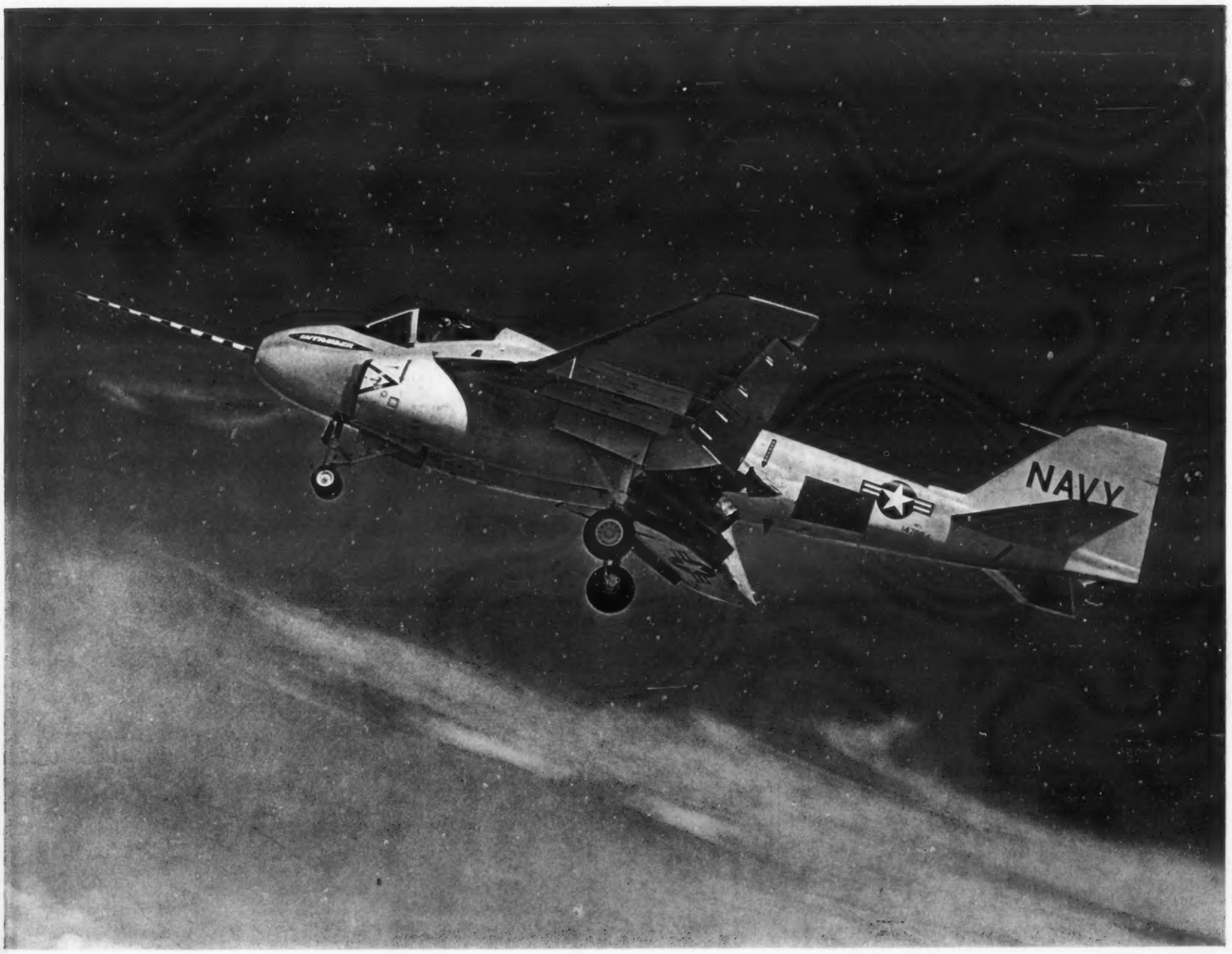
INTERAVIA

World Review of Aviation and Astronautics
with Electronics Supplement



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VOLUME XVI

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Short or Vertical Take-Off?

Review of European and American V/STOL Projects

No. 1 / 1961

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CONVAIR
DIVISION OF GENERAL DYNAMICS

Volume XVI

INTERAVIA

January 1961

WORLD REVIEW OF AVIATION AND ASTRONAUTICS

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Front cover : Take-off of the Grumman A2F *Intruder* STOL combat aircraft with jet nozzles deflected downwards.

Safety will always be Belgian Air Lines' main goal

The transport of persons and property in absolute safety is the constant concern of the management of the Belgian Air Lines, as indeed it is of any air transport company. The priority of safety over all other considerations is stressed both in the general policy directives issued to the staff and in the establishment and observation of the standards for equipment utilization and the working conditions of aircrews.
This regard for safety has also promoted research within the company itself with the aim of producing new and original solutions to problems concerning the comfort and well-being of passengers.
Such research has resulted in the production by Sabena's technical departments of a swing seat, known as the "Braun seat" after the name of its inventor, one of the company's engineers. This seat, normally upright, moves automatically to a horizontal position when the aircraft is subjected to decelerations above a given value, particularly in the case of a hard landing, and enables passengers to withstand far higher decelerations than formerly.
The seat, which has the approval of the Administration Belge de l'Aéronautique, is fitted in Sabena's Boeing 707-329 Intercontinentals.

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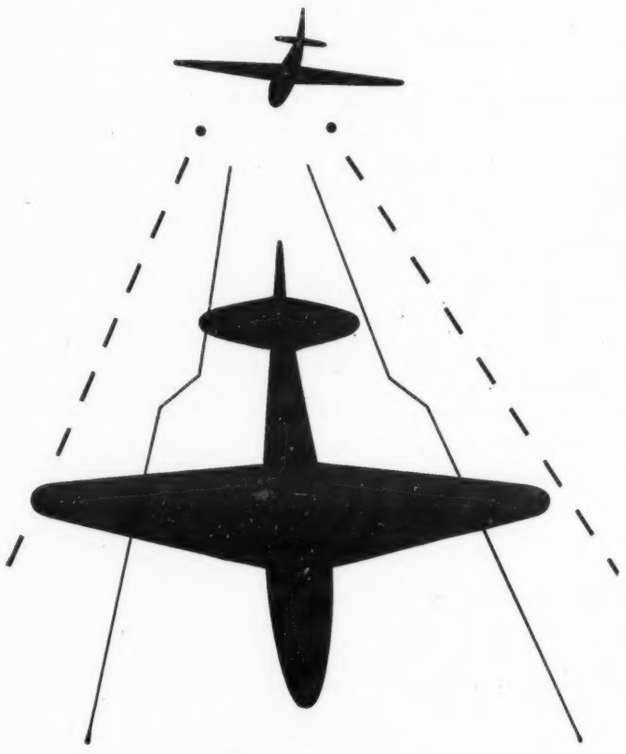
COMING IN ON A WING AND A PAIR OF murphy LEADER CABLES



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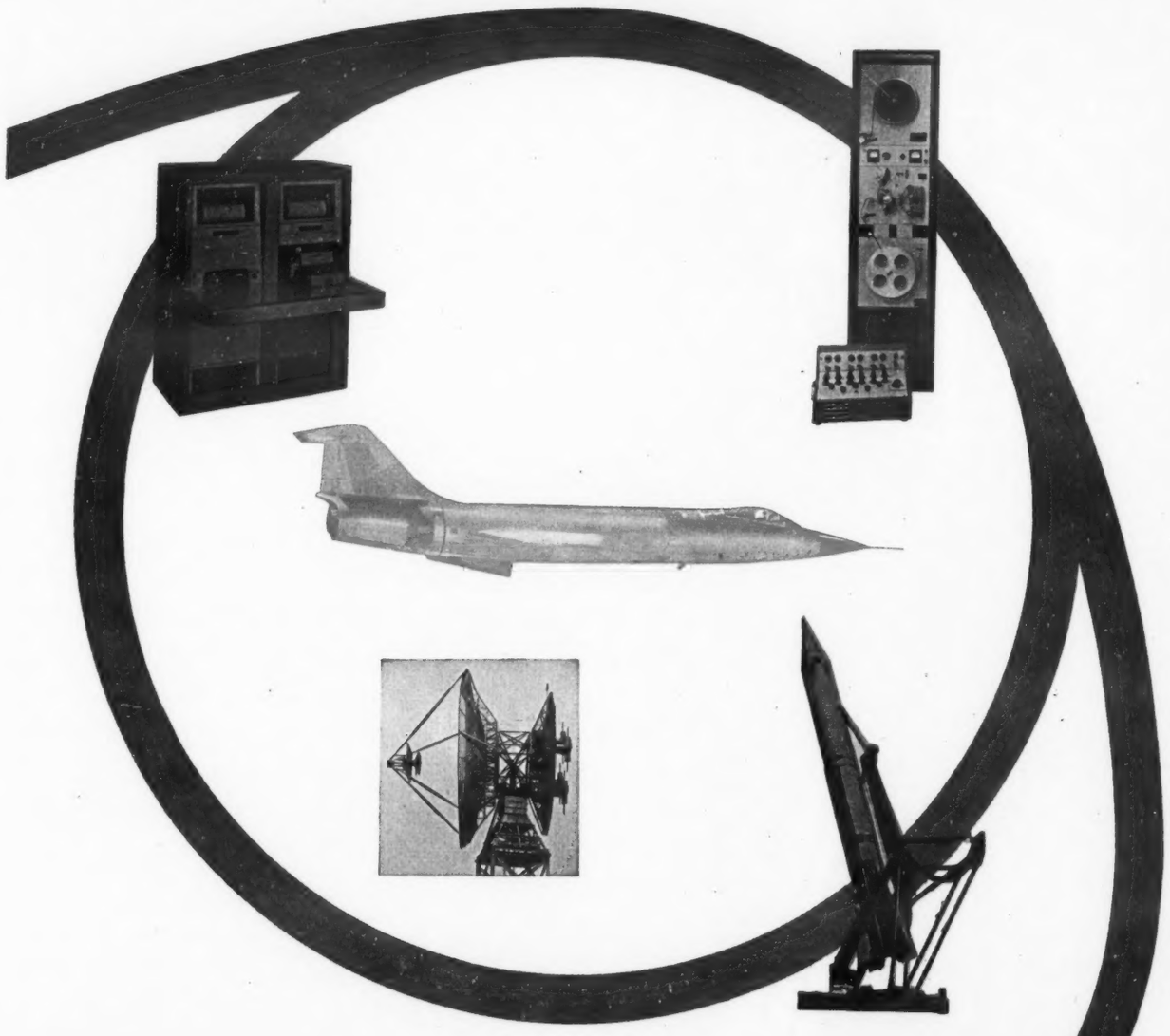

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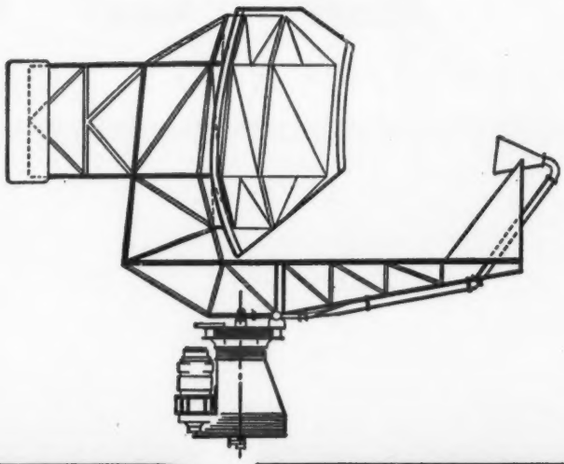

SRE

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To match the increasing use of jet aircraft and the growing density of air traffic, a higher standard of safety precautions is required at airports. PHILIPS long-range Air Route Surveillance radar and Approach Control radar have been specially developed to meet this demand for safe and flexible air traffic control under any circumstances. The utmost reliability is ensured by using high quality components and transistorized circuits. Logical 'unit' construction and many other features permit the formation of radar systems meeting all the special requirements of any airfield. Surveillance Radar Element: another dependable system in the PHILIPS radar programme.

PHILIPS' long-range Air-Route Surveillance radar at Schiphol Airport, Amsterdam

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FIAT G 91 T

BRISTOL SIDDELEY ORPHEUS 80302 JET

The G 91 T taking off from a runway

The G 91 T landing on grass

Fiat G 91 T — Bristol Siddeley Orpheus 80302 engine

The jet trainer with all the characteristics of the G 91, NATO's single-seat lightweight strike fighter, for training pilots in supersonic flight via the intermediate stages of subsonic and transonic flight.
Pilots trained on the G 91 T are ready for assignment to units immediately afterwards.

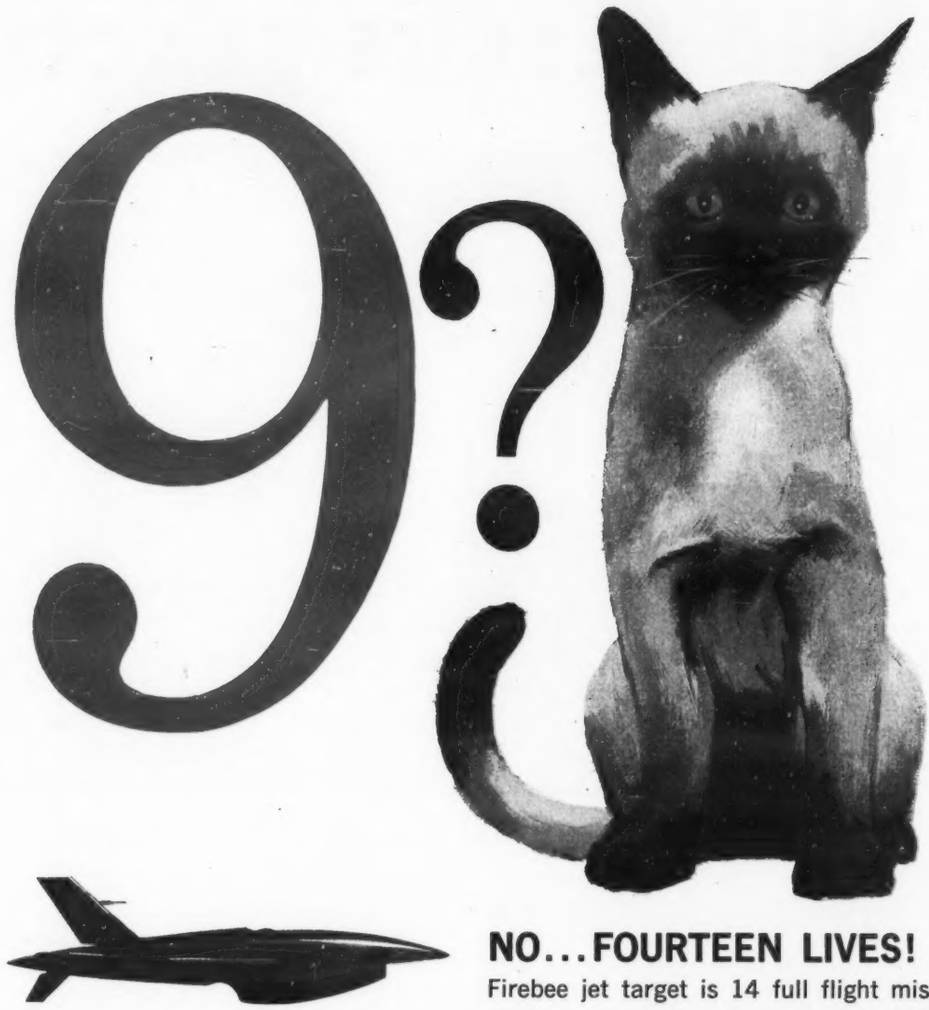
A single aircraft serves both for advanced and operational training, and for combat purposes.

Its similarity to the single-seat fighter makes it ideal not only for advanced and operational training, but also for actual operation on ground support and armed reconnaissance missions.

Principal characteristics and performance figures

Dimensions		*Performance*	
wing span	28.25 ft	speed	transonic
length	38.32 ft	time-to-climb	
height	13.94 ft	to 13,000 ft	4 min 30 sec
		to 26,000 ft	8 min
Weight	11,794 lb	range 1200 n.m. (with two external tanks)	

FIAT – DIVISIONE AVIAZIONE — Corso G. Agnelli 200 — TURIN (Italy)



NO...FOURTEEN LIVES! The average "life" of a Ryan Firebee jet target is 14 full flight missions.* This means that one Firebee can do the work of 14 single-flight expendable drones. And, with a flight duration of up to 1 hour and 43 minutes **(Firebees have flown 1 hour and 17 minutes above 50,000 feet),** Firebees are "on range" long enough to serve an entire squadron of supersonic interceptors or several surface-to-air missile batteries. After missile firings are scored electronically, Firebees parachute to land or sea where they are recovered for use again and again. **Individual Firebees have flown up to 25 missions.** No other target compares with the recoverable Ryan Firebee for high-speed, high-altitude **reliability** and **low cost** per target mission. Newest of the Ryan Firebee family is the **transonic Q-2C,** now in volume production for the Air Force and Navy. Air or ground launched, Ryan Firebees keep more service teams combat ready than all other jet targets combined. And, reflecting Ryan's decade of design and operational experience in the jet target field, improved Firebees will continue to test the mettle of men and missiles well into the Age of Space.

**Based on Q-2C operations at Air Force Missile Development Center*

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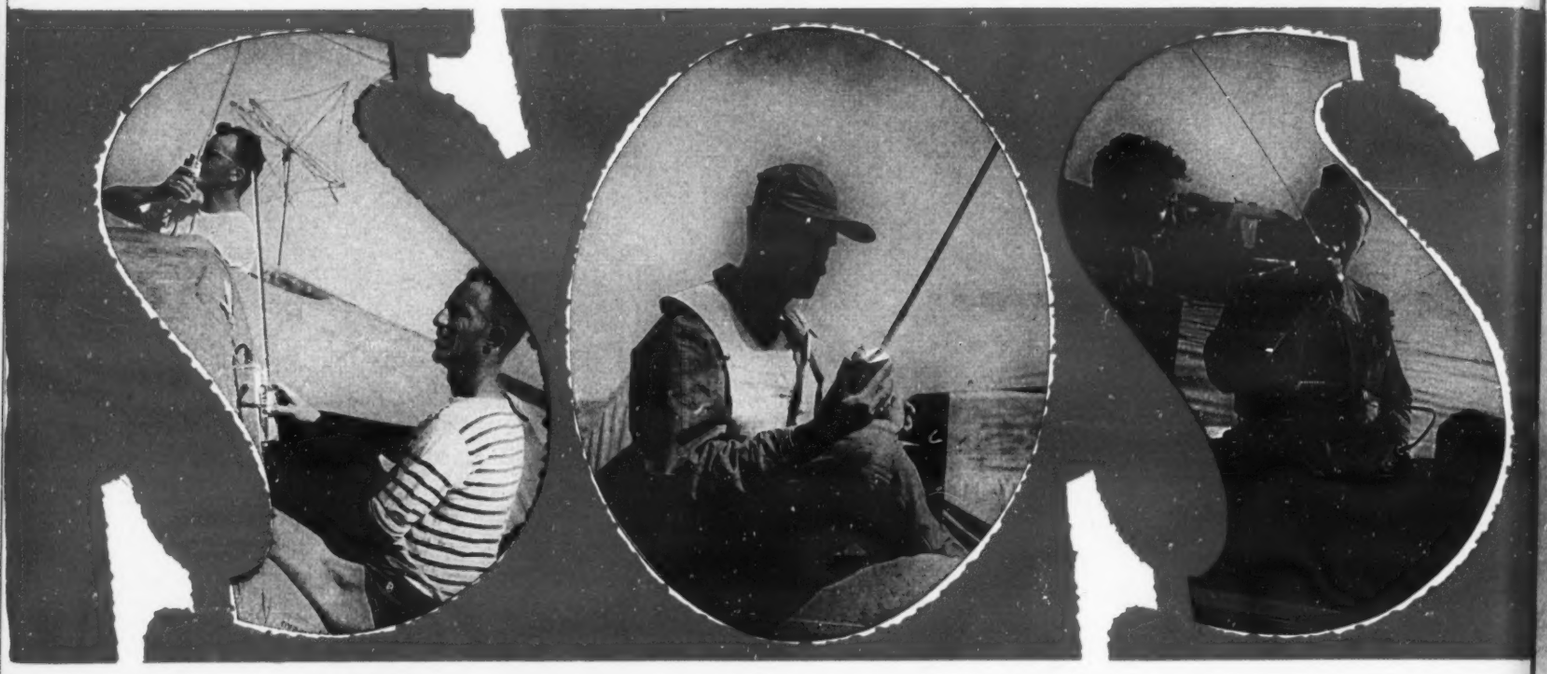

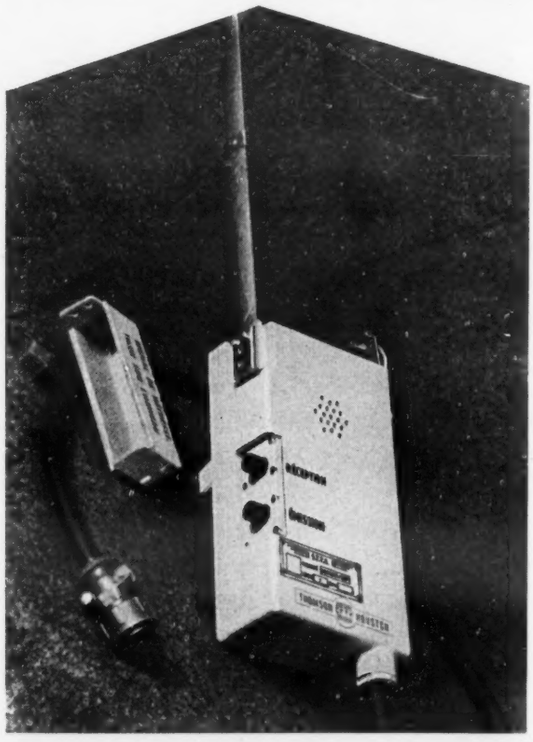

Weighing only 1 lb, the TH.C.986 automatic sub-miniature transmitter-receiver is simple and reliable in operation; it enables a survivor to signal his position to any aircraft with a homing device or a UHF receiver tuned to the distress frequency. Its R/T operation also enables survivors to communicate with aircraft.

Ranges: 30 miles (R/T), 60 to 75 miles (W/T)

The distress signal is automatically transmitted by pulling a ring, and speech communications are made by a unit consisting of microphone and headpiece. The equipment is completely waterproof in up to 13 feet of water. It can be supplied either from a dry battery or from a battery actuated by contact with sea water. TH.C.986 sets are normally preset in the 238-248 Mc/s band and are tuned to the UHF aeronautical distress frequency (243 Mc/s); if required, they can be set to the VHF aeronautical distress frequency (121.5 Mc/s).

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TH.C. 986

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The equipment works in the 225-399.9 Mc/s frequency range on 3,500 channels spaced at intervals of 50 kc/s. Any one of these frequencies can be selected without difficulty. COMPAGNIE FRANÇAISE THOMSON-HOUSTON manufactures a similar 1,750-channel equipment operating in the same range.

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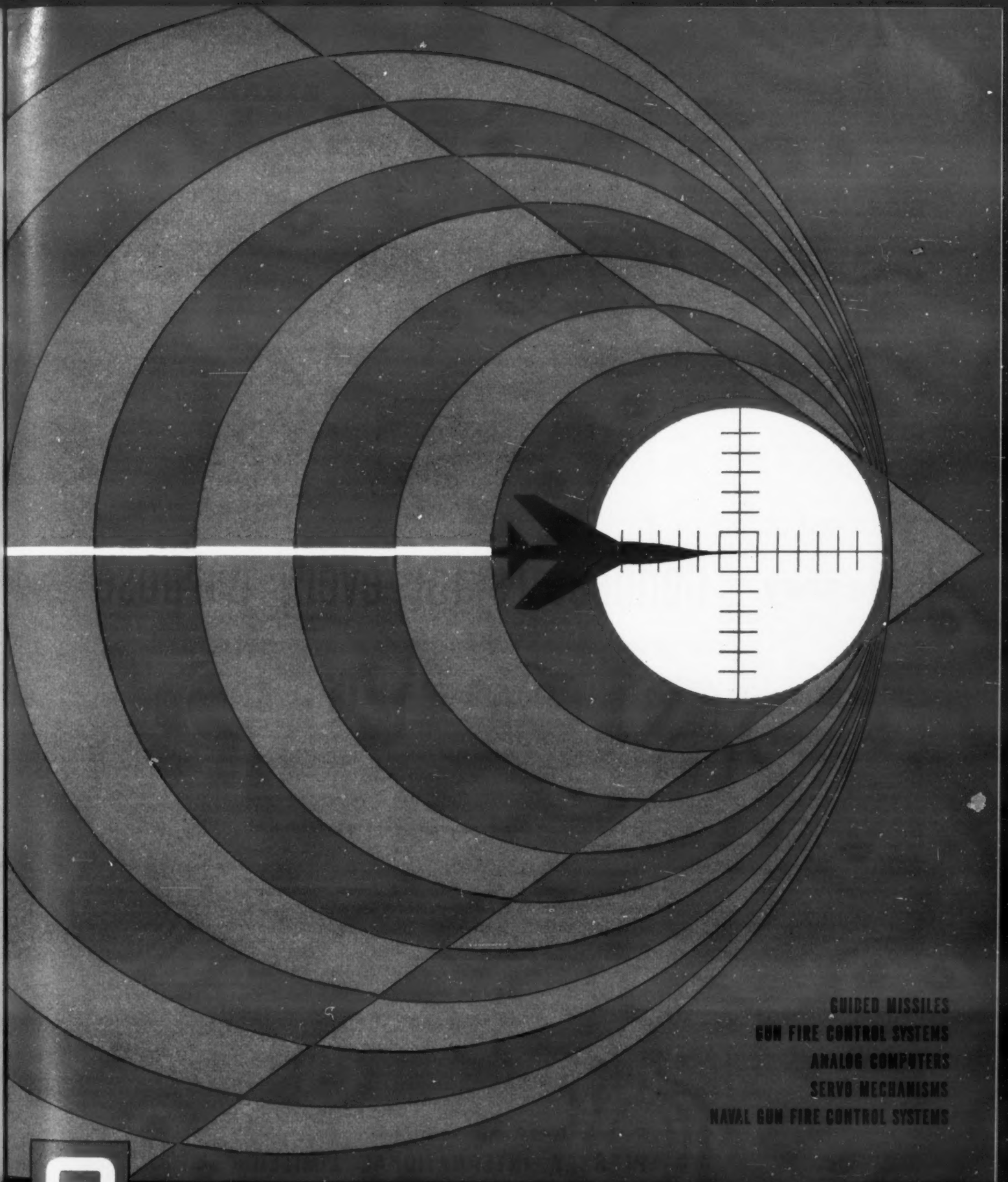

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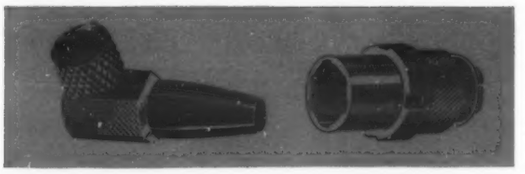

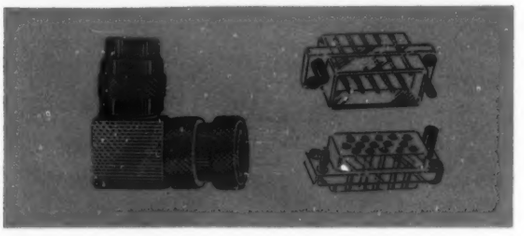

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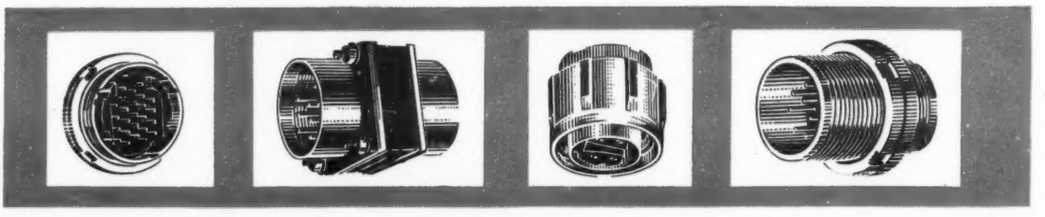

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INTERAVIA AIR LETTER reports...*

Air Transportation

The International Air Transport Association has just published a new edition of the world airline code for the carriage of special cargoes, to become effective January 1st, 1961 on the services of the 136 carriers. Regulations for the packaging, labelling, handling and stowage of nearly 2,200 substances requiring special treatment for carriage by air are contained in an 82-page printed volume. The regulations in this sixth edition have been approved by all interested governments, and a number of States have adopted them into their own air navigation rules making them compulsory on all carriers operating over their territory.

●

The Brazilian carrier VASP (Viaçao Aérea São Paulo) is expected to get Government authorization to operate international services between Rio de Janeiro and certain European capitals, not yet specified. Reports indicate that the carrier is interested in buying VC.10s for this work, and is considering an order for 6 *Caravelles* for domestic operations. Brazilian carrier REAL has received Government authority to take over Panair do Brasil operations on the Rio de Janeiro-Lima-New York route. REAL will start operating the route on receipt of the three Convair 990s now on order.

●

The Japanese Government is expected to make a formal request to the U.S. State Department shortly for discussions towards revising the current U.S.-Japan civil air agreement. Japan Air Lines requires a revised agreement in order to open a Tokyo-Seattle-New York route in 1961, preparatory to launching round-the-world schedules in 1962. Under the current agreement JAL can operate only to U.S. West Coast cities.

●

Air Vietnam has chartered two Viscounts from Air France. The aircraft are being overhauled at Paris-Orly and are due to enter scheduled service with the carrier in the second half of January 1961. The Viscounts will be operated on the routes Saigon-Hong Kong, Saigon-Bangkok and Saigon-Vientiane.

●

Trans-Canada Air Lines took delivery of the first of 23 Vickers *Vanguards* on December 8th, with another 19 scheduled for delivery one a week until May or June. The last three will be delivered early in 1962. TCA will introduce the *Vanguard* into service on transcontinental routes on February 1st.

●

Pan American World Airways will replace Douglas DC-7Cs with DC-8s on African routes effective January 3rd. PanAm will operate a Tuesday flight New York-Dakar-Monrovia-Accra-Leopoldville-Johannesburg, returning each Thursday. A second DC-8 flight will depart New York each Saturday for Santa Maria, Lisbon, Dakar, Monrovia and Accra.

AUA Austrian Airlines has purchased two secondhand Vickers Viscount 745s from Capital Airlines. The aircraft will go to Vickers for overhaul in January and will enter service with AUA in the carrier's summer 1961 schedules. AUA ordered six new Viscount 837s this year, but one was written off in a Moscow crash.

●

Air Force General Felice Santini has succeeded General Renato Abbriata as Italian Director-General of Civil Aviation within the Ministry of Defence (Air). In December, the Italian Senate gave unanimous approval to the draft bill for establishment of a Civil Aviation Commission within the Defence Ministry on its first reading; the bill has gone to the Chamber of Deputies for its second reading.

●

El Al Israel Airlines' Tel Aviv-New York service with a chartered Varig Boeing 707-441 will be inaugurated January 5th on a once-weekly frequency, and Britannia services will be cut from six to five a week. Boeing 707 service will be stepped up to two flights a week on February 19th and four flights a week when the carrier's own 707s are available in May and June. The Varig aircraft will fly under Brazilian colours, with a three-man Brazilian flight crew and El Al cabin personnel. El Al is taking up an option on a third Boeing 707, subject to Government confirmation.

●

THY, Türk Hava Yollari plans to operate five flights a week Istanbul-Vienna, extended twice-weekly to Frankfurt and London and twice-weekly to Zurich, Paris and Lisbon, commencing in April this year. A Turkish delegation was in Vienna in December, and talks are due to be resumed in mid-January.

●

United Arab Airlines-Misrair inaugurated *Comet 4C* service Cairo-Tripoli-Kano-Lagos-Accra on January 1st. UAA has opened a West African Regional Office in Accra under the management of Mohamed Khalifa. Negotiations for the purchase of two more *Comet 4Cs* are in an advanced stage, and UAA will eventually have a fleet of five for international routes and for a projected Atlantic service. The carrier is interested in acquiring two more *Viscounts* on the used aircraft market and is also reported to be interested in the Vickers VC.10.

●

The six Ilyushin IL-18s recently purchased by Ghana Airways were reportedly offered by the Soviet Union at a price of £670,000 ($1,876,000) each. It is understood that the contract includes the cost-free supply of four spare turboprop engine units per aircraft. Payment is believed to be spread over eight years at an interest rate of 2.5 percent, with a down payment of only 10 percent.

Industry

Australia has signed a licence production agreement for the Dassault *Mirage III* to re-equip the Royal Australian Air Force. A contract signed on December 14th covers an initial batch of 30 *Mirages*, but no final decision has yet been announced on the powerplant. The standard model for the French Air Force has the SNECMA *Atar 9*, but tests are to be carried out with an advanced Rolls-Royce *Avon*. Dassault will supply components until the Australian production line is fully established. The programme may be split between the Commonwealth Aircraft Corporation, the Government Aircraft Factories at Melbourne, and de Havilland Aircraft at Bankstown. CAC will undoubtedly build the engines under licence. Paris reports say a CSF fire control system will be used.

●

Republic Aviation and Fokker have confirmed that they will cooperate in the development of a VTOL combat aircraft for NATO. Plans will be submitted to NATO this spring, and a prototype could be flying three years after approval. This would be a supersonic, all-weather, long-range fighter with variable geometry wings.

●

Under the agreement signed with Max Holste, Nord-Aviation has now launched series production of the MH.260 *Super Broussard*, powered by two Turboméca *Bastan* turboprops. Production plans cover 17 aircraft up to the end of 1962, and four a month from January 1963.

●

Sud Aviation's order book for the Turboméca *Artouste II*-powered *Alouette II* helicopter stood at 727 in mid-November, including Belgium's recent follow-on order for an additional 22. Twenty-one countries have placed orders for 381 *Alouette IIs* and 346 are on order for French military and civil requirements. Production is running at the rate of 16 aircraft per month, and the 500th *Alouette* was delivered in December.

●

Massimo Macchia, Manager of Laboratori Elettronici Riuniti, has succeeded Ferdinando Pollastrello as manager of Società Italiana Studi Propulsione Reazione. Pollastrello has been appointed Central Manager of the Finmeccanica Electronics Group. Laboratori Elettronici Riuniti will probably be merged into SISPRE.

●

Ultra Electronics Ltd. will supply communication control and cabin address installations for the 35 Vickers VC.10 aircraft on order for BOAC. The contract is valued at about £100,000 ($280,000) and covers the Ultra UA 60 push-button communication control system, type UA 6000 cabin address amplifiers, and the type UA 6006 cockpit address system.

●

Ferranti Ltd. reports that a prototype of the *Airpass II* (Airborne Interception Radar and Pilot Attack Sight System) now exists, and flight trials are to be carried out by the company's Flight Trials Unit at Edinburgh in a *Meteor*. Later flight trials will be carried out in the *Draken* and *Mirage* in order to prove the complete installations, and programmes have reportedly been agreed with Saab and Dassault.

●

Canadian Aviation Electronics now has orders for 28 Lockheed F-104 simulators, covering six for the RCAF, sixteen for West Germany, four for the Netherlands and two for Belgium. The current orders are valued at about $25 million and the further outlook for additional sales appears to be good. Present employment in Canada stands at 1,284 and when the simulator moves into the production stage, employment will increase by about 600 at the Montreal plant.

●

The National Science Foundation says that the U.S. private industry expended $9,400 million for research and development in 1959,

* Interavia Air Letter is a daily international news digest published in English, French ("Courrier Aérien") and German ("Luft-Post"). All rights reserved.

15 percent more than in 1958. The 1960 R&D expenditures are expected to total approximately $10,000 million. Industries leading in the 1959 R&D programme were aircraft and components ($2,973 million) and electrical equipment and communications ($2.227 million). The Federal Government provided over half (57 percent) of the industrial R&D funds in 1959. This reflects government use of industrial facilities for the conduct of R&D on military and defence materials and equipment in the fields of guided missiles, manned aircraft, space exploration, electronics and atomic energy devices.

●

Boeing Airplane Co. expects to record sales of $1,575 million and net income of from $22 million to $24 million (or $2.75 to $3 per share) for the 1960 calendar year. Sales for 1959 totalled $1,612,152,754. The 1961 sales should produce a net income per share of approximately $4.00. During the 1961 to 1970 period, Boeing estimates that the market will call for 250 long-range aircraft 625 medium to long-range, and 925 short to medium-range aircraft. Boeing's share of the jet transport market to end 1960 is 41.5 percent of the total.

●

Chance Vought Aircraft Inc. has been reinstated as a subcontractor for both vertical and horizontal stabilizers for the North American B-70 *Valkyrie* programme. The value of the contracts is listed only as "multi-million dollar."

●

Bell Aerospace Corp. (a Textron Inc. subsidiary) has received a $26 million follow-on production contract for U.S. Army HU-1B utility helicopters, extending production of the series to the end of 1962. The number of helicopters to be built was not disclosed, but the contract includes spares and ground support equipment. The Bell assembly line is still producing the HU-1A version, and HU-12s are currently being evaluated at Edwards AFB, California.

●

Del Mar Engineering Laboratories has received a $1,072,246 Bureau of Naval Weapons contract to supply air-to-air target training systems for use with the Navy's Chance Vought F8I Crusader.

●

Balduccio Bardocci has resigned his position as President of Alfa Romeo, and is being succeeded by Giuseppe Luraghi. Bardocci retains his seat on the board. Luraghi was earlier Managing Director of Finmeccanica, but left Government employment to return to private industry. This move matches increased Alfa Romeo activity in the aeronautical field. The company has recently acquired a site near Rome-Fiumicino Airport and will build a new facility for the manufacture of components and the overhaul of jet engines, currently carried out at Pomigliano d'Arco. Alfa Romeo is also reportedly interested in the manufacture of rocket components.

Military Affairs

Delivery of the Antonov An-12 aircraft to India is expected to begin in January; less than 10 aircraft have been ordered at a cost of Rs 10 million ($2m.) each. The Indian Government still insists that the An-12s and one Mi-4 helicopter will only be used for road construction work in the Northern Frontier area, airlifting equipment and personnel. The aircraft will, however, have to be flown by Indian Air Force personnel, and although officially owned by the Ministry of Transport they will clearly form part of the IAF Transport Command.

●

The West German Defence Ministry has now confirmed a new order for a further batch of 30 U.S.-manufactured Lockheed F-104Gs. This brings the total of F-104Gs to be supplied to the German Air Force direct from the United States to 96.

●

French Defence Minister Pierre Messmer has announced signature of an agreement with West Germany covering the joint design and manufacture of a single-seat supersonic VTOL combat aircraft. The communiqué added that other NATO and WEU member countries could join in the project if required. The agreement is an extension of existing Franco-German cooperation in the Breguet Atlantic ASW aircraft for NATO and the *Transall* combat zone transport.

●

A joint RCAF-Canadian Defence Research Board team has been carrying out tests on a new Canadian-designed airborne device for the detection of approaching ballistic missiles. For the past eight months a 30-man team with two CF-100s has been stationed at Ascension Island testing the device against missiles launched from Cape Canaveral. The infra-red detection equipment is mounted in wing-tip pods on the CF-100 and is designed to detect and track ICBM nose cones on re-entry into the atmosphere. The objective is to develop effective detection equipment which can be carried in small jet aircraft at an altitude of 40,000 ft above the cloud cover which the infra-red rays do not penetrate. Preliminary tests have proved successful but ultimate employment will depend upon U.S. decision after the equipment has been perfected.

●

Aircraft, Engines and Guided Missiles

A North American A3J-1 carrier-borne Vigilante established a new altitude record on December 13th, 1960, over the USAF Edwards Flight Test Center, California. The *Vigilante* reached 91,446 ft and thus broke the record held by the USSR since 1959 with a height of 67,093 ft. The new record has been submitted to the FAI for confirmation.

●

The four-seat Moskvitch helicopter, designed by Mikhail Mil, is being increasingly used on Soviet feeder services. The *Moskvitch* is derived from the well-known Mil Mi-1, and like the latter is powered by a 575 h.p. Ivchenko AI-26V piston engine. The *Moskvitch* is produced in two versions, with wheel undercarriage and with floats.

●

The Yakovlev Yak-24 passenger helicopter, which in the standard version seats 20 to 30 passengers, is also built in a luxury version for eight passengers. The Yak-24 carries a useful load of four tons; the range is between 210 and 540 nautical miles, while the maximum speed is quoted at about 100 knots.

●

Sikorsky Aircraft is working on a project for a compound helicopter of the *Rotodyne* type, which would be powered by two 2,600 e.s.h.p. General Electric T64 propeller turbines. The all-up weight of the aircraft would be about 18 tons, the cruising speed about 200 knots.

●

A Westland (Saunders-Roe) P.531, powered by a Blackburn *Nimbus* turboshaft engine, is undergoing tropical trials in Aden. A few weeks ago Westland received a substantial order for *Nimbus*-powered P.531/2 Mk.1 helicopters, for use by the Army.

●

U.S. Navy circles are investigating the possibility of equipping the Grumman *Gulfstream* with General Electric T64 propeller turbines, according to unconfirmed reports from Washington. The *Gulfstream* is at present powered by two Rolls-Royce *Darts*.

●

Sud-Aviation is working on a project for a new version of the *Caravelle* jet airliner, known as the *Caravelle X*. Like the recently announced Boeing 727, the *Caravelle X* will be powered by Pratt & Whitney JTF8D-1 turbofan engines delivering 14,100 lb thrust.

●

Pratt & Whitney gives the following supplementary data on the JTF8D-1: take-off thrust (standard day) 14,000 lb; fuel consumption 0.64 lb/lb/h; airflow 305 lb/sec; by-pass ratio 1.1:1; fan compression ratio 1.9:1.

●

The General Electric J85 turbine's thrust-to-weight ratio has been increased from 7.6:1 to more than 10:1 to enable it to be used as a boost powerplant in V/STOL aircraft. The increase in thrust was accomplished by reducing the weight of the engine from 325 lb to less than 300 lb and by increasing speed and temperature. Overall dimensions of the engine are identical with those of the J85-7.

●

Twenty 600 h.p. SNECMA 12T piston engines have been installed in GAMD MD.312 and MD.315 aircraft for endurance tests. Several of these engines have already logged 700 hours without overhaul, and tests are to continue with the aim of achieving an overhaul life of 1,000 hours. The older 12S engines are certificated for an overhaul life of 700 hours; the 12T is an improved version of the 12S.

●

The latest U.S. Air Force guided missile project to become public bears the designation *Muroc Missile*. This is a three-stage solid-propellant ICBM incorporating two new concepts: 1) multi-grain structure of the solid propellant, permitting 100 percent volumetric loading of the rocket motor and simultaneous burnout at all points on the case wall, and doing away with the need for insulation; 2) a vehicle design making available much more volume for propellant loading and simplifying altitude ignition. The *Muroc Missile* is said to be 24 percent lighter and 37 percent shorter than a conventional three-stage solid-propellant ICBM.

●

A three-stage research rocket, with RAE Farnborough first stage and second and third stages by the Australian Weapons Research Establishment, reached a maximum speed of over 7,000 m.p.h. at an altitude of 80,000 ft. The first stage boosted the rocket to the planned altitude of 80,000 ft; the second and third stages accelerated it to 7,000 m.p.h. in near horizontal flight. These experimental rockets are being used to investigate the effects of extreme friction heating on various materials.

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The GNOME

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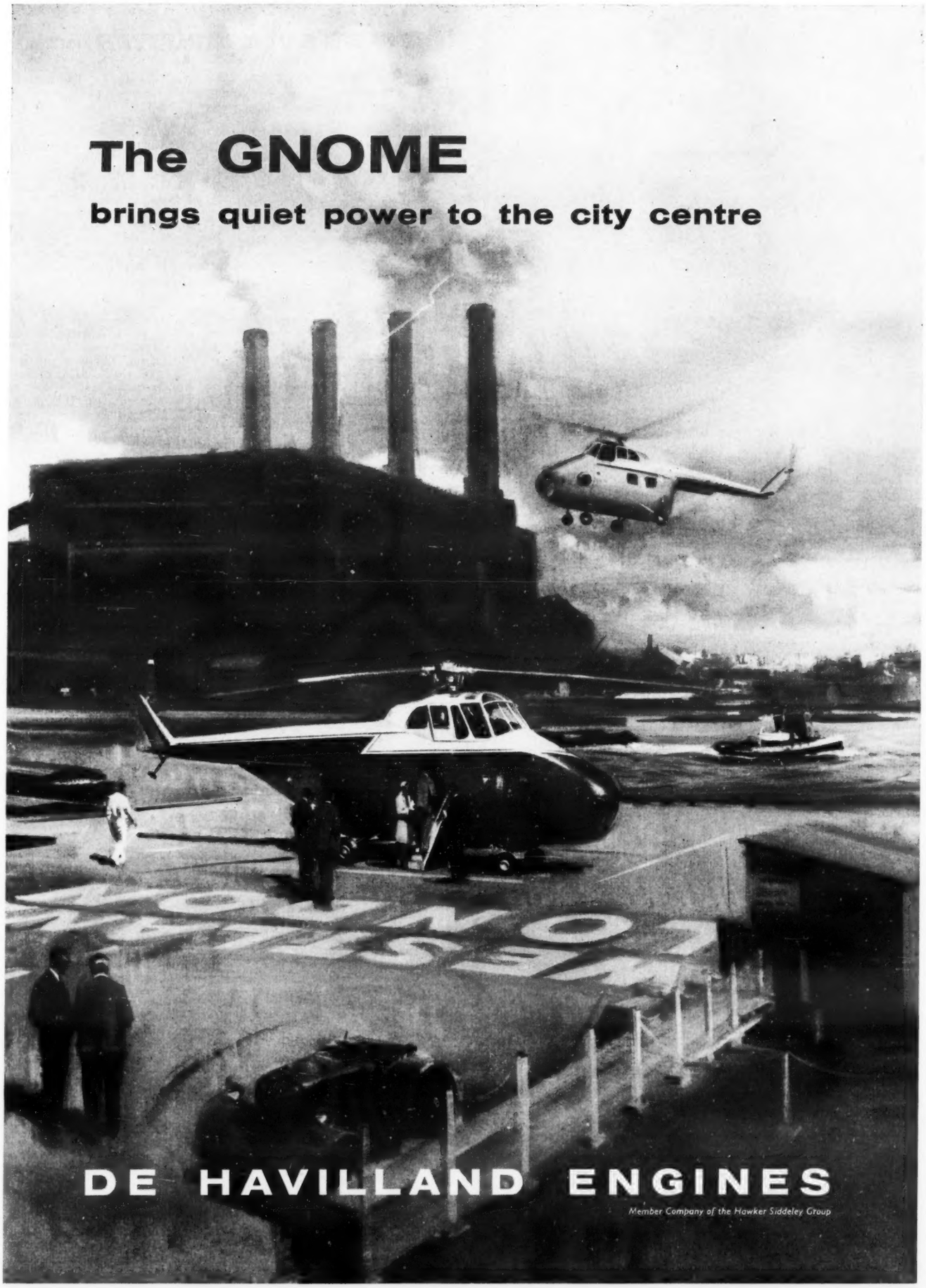


DE HAVILLAND ENGINES

Member Company of the Hawker Siddeley Group

The Ampex FR-700 wideband magnetic tape system can function as a universal predetection telemetry recorder. This ground-based companion to the airborne AR-300 both records and reproduces, and will play back tapes recorded on any Ampex AR-300. Bandwidth data is FM recorded using a 6 megacycle carrier. Rotating magnetic heads record transversely, one wideband channel for one hour at 12½ ips., or two wideband channels simultaneously for one-half hour at 25 ips. Input power is 1200 watts at 50 or 60 cycles. For specifications write to Ampex Great Britain Limited, Arkwright Road, Reading, Berks., England. AMPEX

INTERAVIA AIR LETTER Reports...

(contd. from page 20)

Aircraft and Powerplants

The Breguet 945 STOL transport, on which design studies are now being carried out, will be powered by two Turboméca *Turmo IIIDs* driving four propellers. With a take-off weight of 10 tons, the aircraft will have a payload of 3,300 lb over stage lengths of up to 810 n.m. at an average cruising speed of 215 knots. Take-off distance will be roughly 300 ft at sea level, or some 650 ft from fields at 3,300 ft altitude or in tropical conditions. Smallest radius of turn is estimated at 230 ft. The Breguet 945 will be suitable for a wide range of missions, including reconnaissance, ground support, transport of troops and supplies, air ambulance, and aerial survey work. A pressurized civil version would be able to accommodate 20 passengers.

●

The Canadair CL-44 cargo aircraft's runway requirements for both take-off and landing have been improved by 11 to 12 percent as the result of recent flight test measurements. The balanced field length for take-off has been reduced to 6,800 ft from 7,660 ft, and the landing field length is reduced to 5,980 ft from 6,780 ft. These reductions in field lengths apply to the maximum take-off weight of 205,000 lb and to the maximum landing weight of 165,000 lb. The first CL-44 began flight tests on November 16th.

●

The French company SNECMA has begun work on a project for an engine, the M-35, for medium-range aircraft with cruising speeds between Mach 2 and Mach 3. The company has also begun a joint study with Turboméca on a lift-jet prototype.

●

Two Blackburn Buccaneer naval strike aircraft are at present in the Mediterranean area for the second series of deck trials, which will take place on the aircraft carrier " Ark Royal. " Initial deck trials with the *Buccaneer* were carried out last January on the "Victorious" in the English Channel.

●

Gluhareff Helicopters, Van Nuys, California, announces that its G8-2 pressure jet engine is now available to the general public. This engine, which was designed specifically to use liquid propane as fuel, weighs only 5 lb and is reported to have a life expectancy of well over 1,000 hours without maintenance. The G8-2, which develops 15 h.p., has been specially designed for use on helicopters (rotor blade tip mounted), autogyros, flying platforms etc.

Accessories and Equipment in Brief

General Electric Company has developed a new X-band voltage-tunable magnetron which can be used to drive local oscillator tubes in telemetry, electronic countermeasures etc.

●

Tall Tom is the U.S. Air Force code name for the AN/ULD-1 Electronic Reconnaissance System, under development since 1958 at Hoffman Electronics. Details of *Tall Tom* are classified, but it is stated that the system is at present in its bench test phase.

●

Lockheed's Special Products Branch has designed, built and delivered its first " Verti-Stand," a new pneumatically operated working platform for maintenance duties. The new stand can lift a load of 750 lb to a height of 41 ft; weight is 4,200 lb.

●

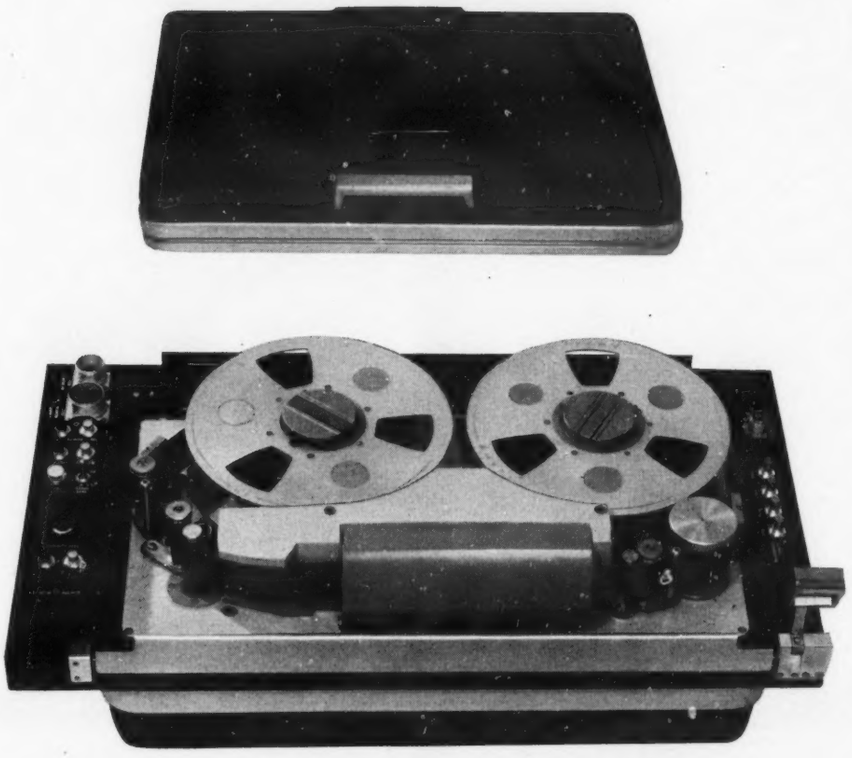
The SIGMA 4 wind tunnel at St. Cyr, run by the Conservatoire National des Arts et Métiers, has gone into operation. It works with SNECMA/Frenzl hot water ejectors and is suitable for subsonic, transonic and supersonic measurements.

●

Three versions of new spray pumps for agricultural aircraft are being marketed by Agricultural Aviation Engineering Co., Santa Clara, Calif. The pumps are designed for application rates in excess of 10 U.S. gal./acre.

●

A new axial-flow shutoff valve developed and manufactured for a NASA project by Whittaker Controls Division of Telecomputing Corp., Los Angeles, will be employed in deep space probes. Metal-to-metal design to limit leakage to 1 cm^3 per hour was dictated by environmental requirements. Weight 3 ounces; operating pressure 15 psi; power consumption 2 watts; actuating voltage 25 volts d.c.; opening time 4 milliseconds; closing time 13 milliseconds; ambient temperature $-100°C$ to $+100°C$.



The Ampex AR-300 airborne magnetic tape recorder
offers 16 times the frequency response of existing wideband equipment. New applications in video bandwidth recording such as radar tracking and reconnaissance, simulation and wideband communications monitoring, are now practical because the AR-300 – and its ground-based companion, the FR-700 – employs rotating magnetic heads... a principle pioneered by Ampex and now in use by more than 650 VIDEOTAPE* Television Recorders throughout the world. Two channels of wideband information can be captured over a data spectrum from 10 cps to four megacycles, ±3 db. Simultaneously, two auxiliary information channels, with frequency response from 200 cps to 15 Kc, are recorded linearly along the edge of the tape. Solid-state components and advanced packaging techniques case-shock mounted provide a recording system that displaces only 3½ cu. ft., weighs less than 150 lbs. To obtain a highly accurate time-base relationship, tape is pre-heated prior to recording. A heat exchanger maintains constant ambient, insuring reliable operation of the AR-300 under extreme environmental conditions. For specifications write to Ampex Great Britain Limited, Arkwright Road, Reading, Berks., England. AMPEX

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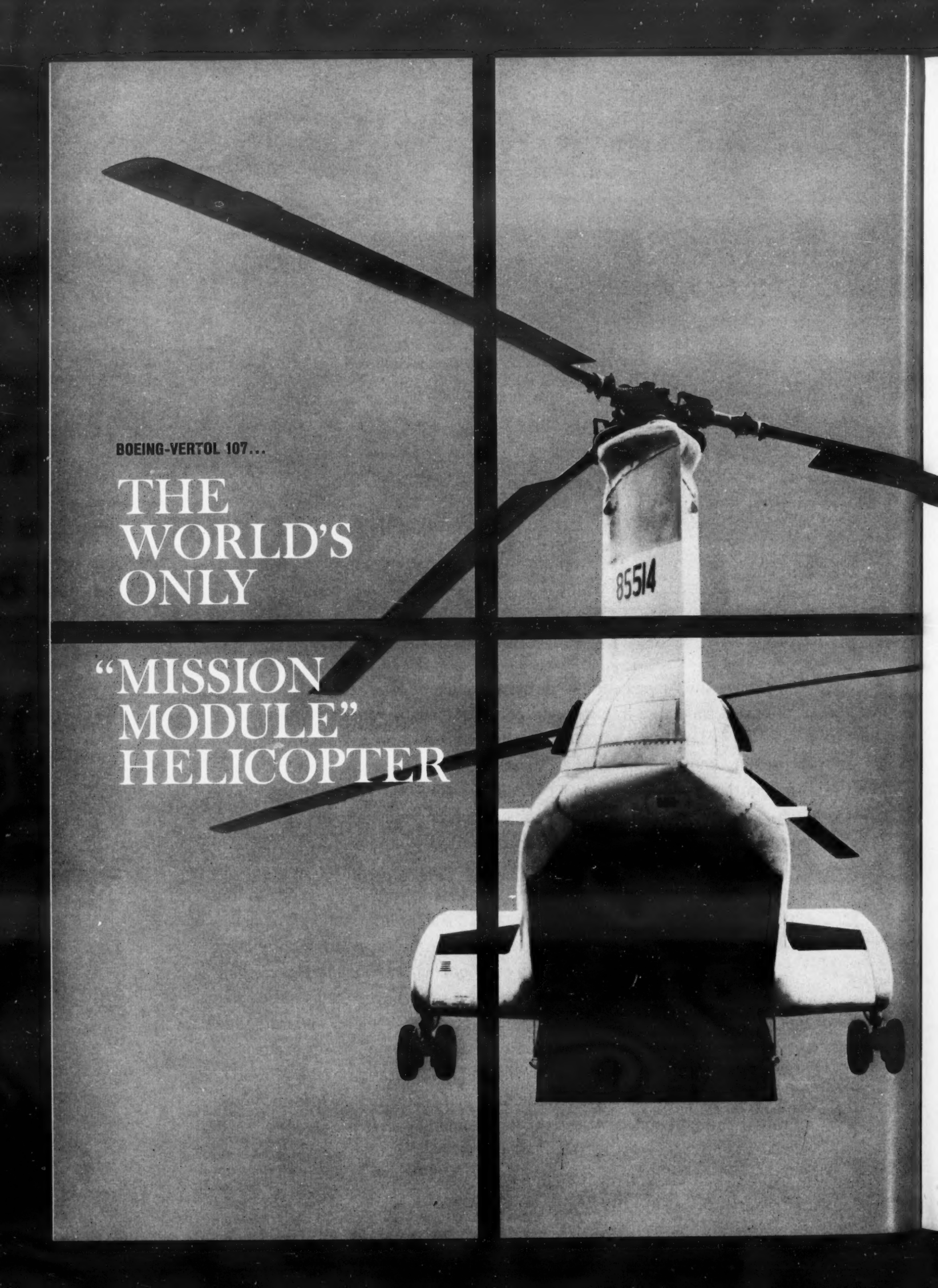
BOEING-VERTOL 107...
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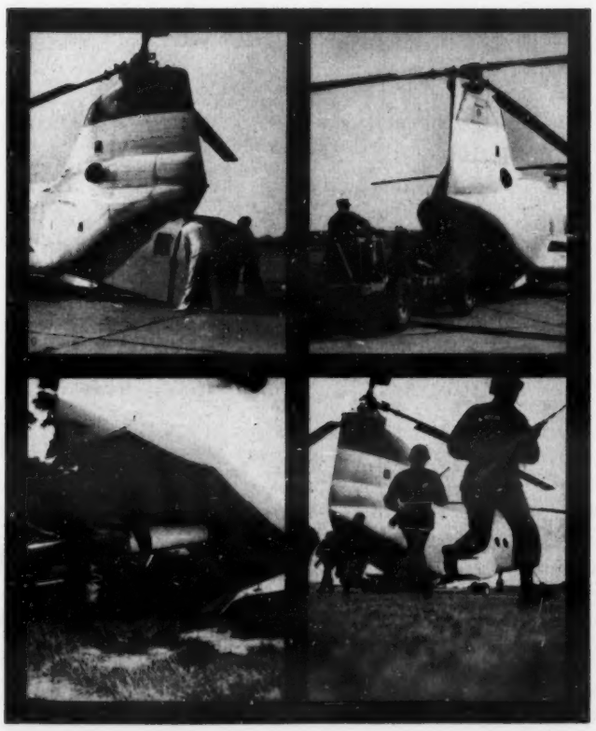
CONVERTS FROM MINESWEEPING TO ASW IN ONE HOUR

The new twin turbine-powered Boeing-Vertol 107 is the only helicopter flying today that can perform so many military missions—without costly conversion of the basic aircraft. The rear loading ramp and unobstructed cargo area permit a variety of modules or equipment to be quickly and easily installed on the 107, thereby enabling it to perform specialized missions for any and all military services. The Navy, for example, can use the Boeing-Vertol 107 for minesweeping and fleet utility duties and then, less than sixty minutes after mission completion, convert to anti-submarine warfare—simply by installing Vertol's ASW module.

Whatever the mission, the performance-proved Boeing-Vertol 107 offers features unmatched by any other helicopter—150 mile-an-hour cruise speed . . . neutral directional stability at zero airspeed for any-wind hovering . . . a Vertol-developed stability augmentation system (SAS) provides fixed-wing aircraft stability which can be augmented with a trim system for automatic flight . . . tandem-rotor design that minimizes downwash velocities . . . ability to land and take-off from water without special flotation gear.

These are just a few of the capabilities that make the Boeing-Vertol 107 the *first* all-mission, all-service helicopter.



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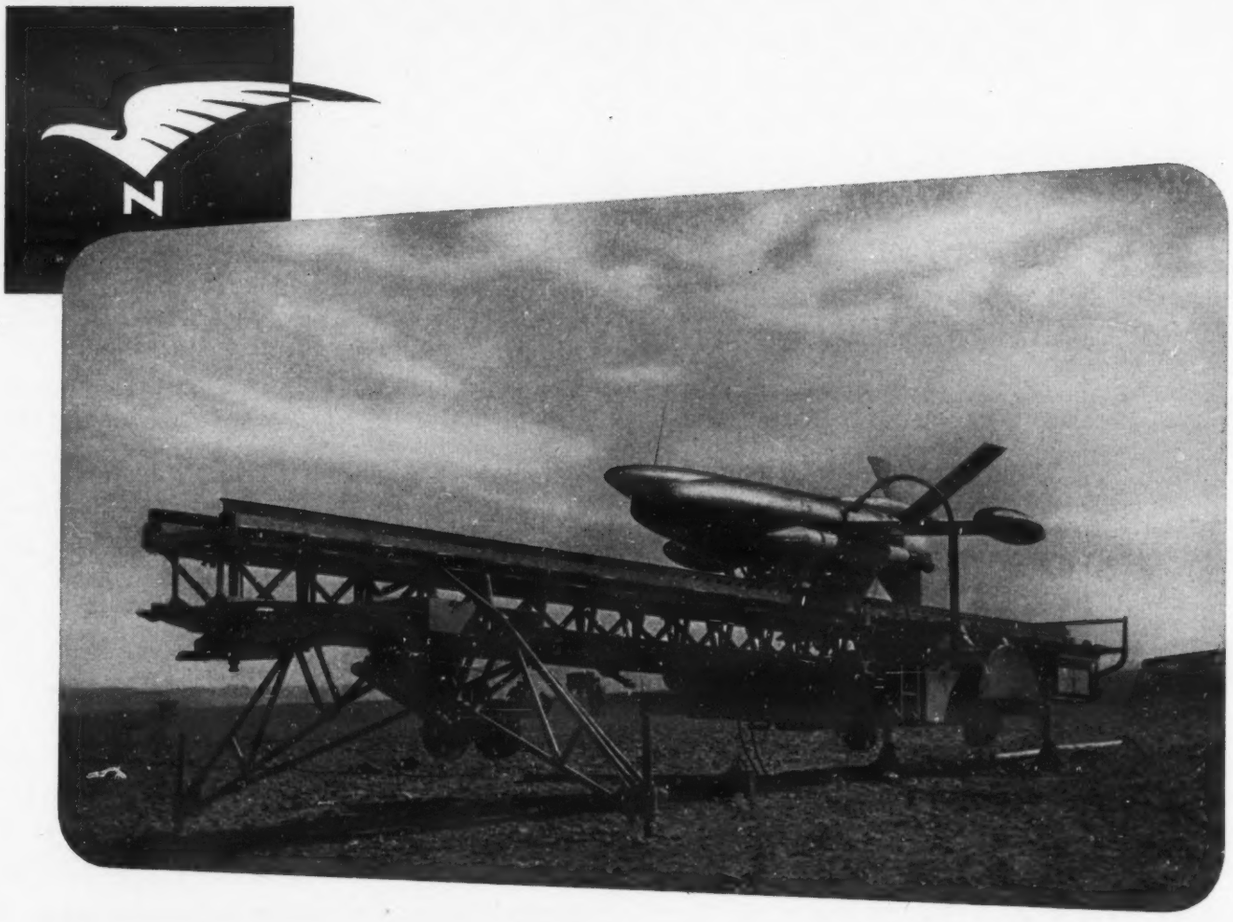

CT. 20

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This single AiResearch ground power package provides all of the electrical and pneumatic power needed to meet the increased ground support requirements of the newest jet transports. At the same time, the new dual-purpose GPV-91 results in a unit that effects considerable dollar savings over separate units to provide pneumatic starting and electrical services.

The 120 KVA power package doubles previous electrical output of support systems to supply all power for ground checkout and heating... and enables Freon refrigeration systems to operate at maximum capacity during the entire ground operation in hot weather.

The compact power unit consists of an AiResearch GTCP 85-91 gas turbine driving a 120 KVA alternator. This gas turbine features automatic operation and pushbutton starting, operates in any weather extreme from −65° to 130°F. Optional 28 volt dc power is available up to 1600 amperes.

This lightweight power package can be installed on nearly any vehicle or carried as an onboard unit. AiResearch has delivered more than 9000 gas turbines in the 30 to 850 hp range. For further information, write to Garrett International S.A., Rue des Pierres-du-Niton 17, Geneva, Switzerland.

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The Boeing 727

In December 1960, the Boeing Airplane Co. announced receipt of orders valued at $350 million for 80 Boeing 727 medium range jet transports. These orders marked the culmination of a design study which has been in progress for the past four and a half years.

The studies were undertaken with the object of determining the best combination of airframe and engines to make possible the low cost-per-mile operation which was essential to compete with the turboprop aircraft. During this period, 150 different airliner designs were analyzed in detail, and 68 models actually underwent more than 1,500 hours of wind tunnel testing.

Parallel to the design work, a route survey was carried out on all the major U.S. domestic airline routes. This survey enabled the company to establish the economic and operational requirements which had to be met to ensure that the new aircraft fulfilled the low-cost and short field performance which was essential.

An early design in the programme was the model 727-257, which was a twin-engine airliner with the engines in pods mounted on struts above and behind the wing. This was followed by the 727-265 with two conventional underwing pods similar to the 707. Studies were also carried out with the model 727-264C in which the two engines were carried in pods on either side of the aft fuselage.

The economics of a four-engine airliner were also taken into consideration. The model 727-475, which was similar to the 720 in configuration, but on a reduced scale, was examined, and it was determined that both the twin- and four-engine aircraft lacked the cost performance required for medium haul operations.

On June 1st, 1959, the full-scale project was commenced on the basis of a three-engine layout. The fuselage width selected was the same as the 720 and 707 so as to offer the maximum capacity and earning power in a tourist or mixed class configuration. To keep manufacturing costs to the minimum it was also decided to use tooling employed in the construction of the 707/720 series. With the exception of modifications which have been developed as a result of operational experience, the aircraft systems installed on the 727 will be similar to those used in the earlier and larger aircraft.

The configuration of the aircraft as finally announced displays many points of difference to the larger predecessors. The three engines are mounted at the rear of the fuselage with the outer engines in pods and the centre engine buried within the fuselage. Apart from the advantages derived from the engine location at the rear in conditions of asymmetric thrust, this layout also leaves the wing clear for the maximum use of high-lift devices. To fulfil the objective of giving the 727 a superior short-field landing and take-off performance, Boeing has aimed at achieving a maximum lift coefficient of 2.5. It has since been rumoured that the figure finally attained is closer to 2.8.

The wing planform reveals a 32 degree sweepback at quarter chord. Triple slotted flaps are fitted at the trailing edge, but no information has yet been received as to whether any form of flap blowing is employed. On the leading edge inboard section, flaps are installed similar to those used on the Boeing 707. The outboard leading edge sections carry slats which extend forwards and downwards at low speeds to form slots. In cruising flight the slats are retracted into the leading edge of the wing to preserve the high-speed characteristics.

The engines selected for the Boeing 727 are Pratt & Whitney JT8D-1 turbofans of 14,000 lb thrust. This engine is a development of the J52 turbojet which was planned for the Naval A4D attack aircraft. After cancellation of this programme a modified version of the J52 was used to power the *Hound Dog* air-launched missile. A further model is installed in the Grumman *Intruder* aircraft.

As the rating of the J52 lies between 7,500 and 8,000 lb, it is obvious that the new JT8D-1 is a considerably bigger engine and one which stems from a background of military rather than commercial applications.

The control systems designed for the new airliner exhibit some changes, in comparison with the installation on the 707 series. In the larger aircraft, the control surface actuation is essentially manual on the ailerons and elevators, and manual with hydraulic assistance on the rudder. In the 727, a system of dual hydraulic units assists the surface movement in all three senses. This can be described as a manual system with hydraulic boost, as the aircraft can be controlled without hydraulic assistance if the need should arise.

Apart from this fundamental difference in the control actuation, the remainder of the system installations are similar to 707 practice, and wherever possible identical equipment has been used. Electrical power supply is mainly alternating current with transformer-rectifiers providing direct current for certain items of equipment.

The history of the development of the Boeing 727 in model form. In the background is the model 257 (left) and the 265 (right). Centre left is the model 475, which was called the 720 Jr. by Boeing engineers because of its similarity to that aircraft. The interim and finalized designs for the three-engine configuration stand in the foreground.

Boeing 727 Specifications

Wing span	108 ft
Overall length	134 ft 1 in.
Height	33 ft 9 in.
Max. gross weight	142,000 lb
Max. landing weight	131,000 lb
Cruising speed	550 to 600 m.p.h.
Cruising altitude	15,000 to 35,000 ft
Range	1,700 miles
Passenger capacity	70 to 114
Capacity payload	24,000 lb
Take-off field length (max. take-off weight)	5,000 ft
Powerplant	
3 Pratt & Whitney JT8D-1 turbofans	
Take-off thrust	14,000 lb (standard day)
Specific fuel consumption	0.64 lb/lb. t/hr
Airflow	305 lb/sec
Bypass ratio	1.10

It is interesting to note the trend toward a bypass ratio of unity in commercial fan engines. It would appear that the increase in engine weight and nacelle drag due to the increased size and diameter of the high bypass ratio engines makes the unity bypass ratio the most economic proposition for commercial operations.

*

The technical data for the Boeing 727 are listed in the accompanying box together with details of the engine performance. The aircraft represents the product of a lengthy study of operational requirements and market research.

In terms of performance and operating costs, Boeing states that the average direct cost of flying the 727 on a 500 mile trip is about $1.50 per mile. In a first-class configuration the direct operating cost per seat-mile is very nearly the same as that of the latest American turboprop airliner, while in the tourist configuration the direct operating cost per seat-mile is more than 10 percent greater for the turboprop than for the 727. This economy in operation, together with its size, enables the aircraft to provide the capacity required during peak traffic periods, and also operate at a minimum cost per mile on low density routes.

INTERNATIONAL MEETINGS AND CONFERENCES

Jan. 3rd-23rd: ICAO, Limited European-Mediterranean Rules of the Air and Air Traffic Services/Communications Regional Air Navigation Meeting. Paris.

Jan. 8th-12th: Joint Technical Society/Department of Defense Symposium on Thermoelectric Energy Conversion. Dallas, Tex.

Jan. 9th-11th: Seventh National Symposium on Reliability and Quality Control. Philadelphia, Pa.

Jan. 9th-13th: Society of Automotive Engineers, International Congress and Exposition. Detroit, Mich.

Jan. 15th-18th: Helicopter Association of America, 13th Annual Convention. Haddonfield, N.J.

Jan. 16th-18th: American Astronautical Society, Seventh Annual National Meeting. Dallas, Tex.

Jan. 16th-20th: 45th Physical Society Exhibition. London.

Jan. 17th-19th: Instrument Society of America, Winter Instrument-Automation Conference and Exhibit. St. Louis, Mo.

Jan. 21st: Society of Environmental Engineers, "Development of accelerated climatic tests." London.

Jan. 23rd-25th: Institute of the Aeronautical Sciences, 29th Annual Meeting. New York.

Jan. 24th: IATA Traffic Conferences: special conference on freight rates. Paris.

Jan. 30th-31st: Royal Canadian Flying Club Association Annual Convention. Chateau Laurier, Ottawa, Ont.

Feb. 1st-3rd: American Rocket Society, Solid Propellants Conference. Salt Lake City, Utah.

Feb. 1st-3rd: Institute of Radio Engineers, 2nd Winter Military Electronics Convention. Los Angeles, Calif.

Feb. 7th-9th: The Society of the Plastics Industry, 16th Reinforced Plastics Division Conference. Chicago, Ill.

Feb. 15th-17th: Institute of Radio Engineers, International Solid-State Circuits Conference. Philadelphia, Pa.

Feb. 27th-28th: Canadian Aeronautical Institute, Mid-Season Meeting. Winnipeg, Man.

Mar. 5th-9th: American Society of Mechanical Engineers, 6th Annual Gas Turbine Conference and Exhibit. Washington, D.C.

Mar. 9th-10th: University of Pennsylvania, 2nd Symposium on Engineering Aspects of Magnetohydrodynamics. Philadelphia, Pa.

Mar. 9th-10th: Institute of the Aeronautical Sciences, Flight Propulsion Meeting (classified). Cleveland, Ohio.

Mar. 12th-16th: American Society of Mechanical Engineers, Aviation Conference. Los Angeles, Calif.

Mar. 13th-15th: American Rocket Society, Flight Testing Conference. Los Angeles, Calif.

Mar. 13th-16th: American Rocket Society, Test, Operations and Support Conference. Los Angeles, Calif.

Mar. 13th-22nd: International Spring Fair. Utrecht.

Mar. 14th: ICAO, Subcommittee of the Legal Committee on Aerial Collisions. Paris.

Mar. 16th-18th: Fifth National Conference on Aviation Education. Washington, D.C.

Mar. 20th-23rd: Institute of Radio Engineers, International Convention. New York.

Mar. 20th-24th: American Society for Metals, Western Metal Exposition. Los Angeles, Calif.

Mar. 27th-31s: National Symposium on "Temperature—Its Measurement and Control in Science and Industry." Columbus, Ohio.

The New President Faces the Old Military Problems

During the electoral campaign, President Kennedy left no doubt that, although he did not in any way wish to cut the United States defence forces, he intended to modernize the defence organization with a view to improving its efficiency and achieving economy.

In order that his promise should be something more than empty words, he set up a six-man committee under the chairmanship of Senator Stuart Symington, a committee which included Thomas K. Finletter, former Secretary of the Air Force and originator of the well-known report "Survival in the Air Age," published in 1947. The Symington committee, which was originally supposed to submit its report by December 31st, did so in mid-December, and made the following recommendations: 1) the Secretary of Defense should have the sole authority to administer defence funds; 2) the Chiefs of Staff of the three armed services should be directly responsible to the Secretary of Defense, and the Departments of the Army, Navy and Air Force should be abolished; 3) the Joint Chiefs of Staff should be superseded by a single Joint Staff Chairman, who would be directly responsible to the Defense Secretary and would be assisted by a purely advisory committee of officers from the three armed services; 4) to maintain the basic structure of the armed services, but to divide them into four separate commands: *Strategic Command* for the strategic missions of a nuclear world war; *Tactical Command* for limited operations; *Defense Command* for the defence of the American homeland; and *Civil Defense Command* for the protection of the population.

The acceptance of Symington's recommendations would mean nothing more or less than the replacement of the existing democratic organization of the American fighting forces by a rigid hierarchy. That a plan of this kind would raise violent storms in all quarters—Army, Navy and Air Force—was to be foreseen. The instigator of the report, President Kennedy, has so far confined himself to the following sibylline utterance: "It is an interesting and constructive study, which I know will be carefully analyzed by the Congress and the incoming Administration."

Be that as it may, the new Administration will still have to come to grips with one of the oldest problems of the American defence organization: the rivalry between Army, Navy and Air Force. This rivalry led in 1949 to the USAF/Navy duel over the question "Convair B-36 long-range bomber or large aircraft carrier," and in 1957 to the equally bitter battle between all three defence branches over who was to be responsible for developing the ICBM, a dispute which was temporarily ended only by the then Defense Secretary, C. E. Wilson.

The rivalry is no less keen today. With its *Polaris* submarines, the Navy once again energetically turned to strategic warfare, earlier regarded by the USAF as its exclusive preserve; and the Army is toying with the idea of a highly mobile version of the *Polaris* for continental operation. All three defence branches have various competing specifications in hand for a number of guided missile categories, and there are serious differences of opinion as regards the allocation of tactical aircraft among the three services. This brings us to the crux of the U.S. materiel problem, to triplication in the procurement and operation of new weapons or, briefly, to questions of hard cash. Before these lines appear in print, the Eisenhower Administration will submit the draft budget for fiscal 1962, which the Kennedy Administration will have to get accepted—by the armed services, Congress and the taxpayer. The fiscal 1962 draft budget will reportedly be maintained at last year's level—$41,500 million.

It is understandable that all three armed services will press for a substantial increase in their appropriations, in view of the ever-increasing requirement for materiel to meet every possible contingency. President Kennedy and his newly-appointed Defense Secretary Robert S. McNamara will not only have to ward off the various Pentagon departments with their special wishes; they must decide on the further policy to be pursued jointly with the other Western Powers, and they have at the same time the unpleasant duty of standing firm before their country's European allies, maintaining the former Administration's policy as regards the reduction of the American contribution to the common NATO defence effort. In this connection, a reference to the defence expenditures of individual NATO States may be of assistance. The proceedings of Western European Union for June, 1960 contains the following table, in which the 1959 defence expenditures of NATO States have been converted into dollars and compared with populations and national incomes.

The Defence Expenditure of NATO States

	Population in 1958 (millions)	Defence expenditure in 1959 ($ million)	Defence expenditure as percentage of gross national income 1959
1. USA	174.8	46,318 *	10.6
2. Canada	17.1	1,794	5.9
European NATO States			
3. Great Britain	52.0	4,511	7.8
4. France	44.6	3,670	8.9
5. West Germany	52.1	2,745	5.7
6. Italy	48.7	1,018	4.2
7. Netherlands	11.2	401	4.3
8. Belgium	9.1	394	3.8
9. Turkey	26.2	244	5.0
10. Greece	8.1	163	6.0
11. Norway	3.5	152	4.0
12. Denmark	4.5	149	3.2
13. Portugal	9.0	93	4.7
14. Luxemburg	0.32	8	1.9

* This takes account of items from other budget headings, which have been added to the sum of $41,500 million mentioned earlier in this article.

In other words, 175 million Americans spent $46,300 million on defence in 1959, while 270 million Europeans spent only $13,500 million for the same purpose.

How far President Kennedy can expect his fellow-countrymen to continue making sacrifices, or how far he thinks the common defence needs of the Western world merit priority, will become clear in the State of the Union message, the budget proposals and the ensuing budget debates in Congress.

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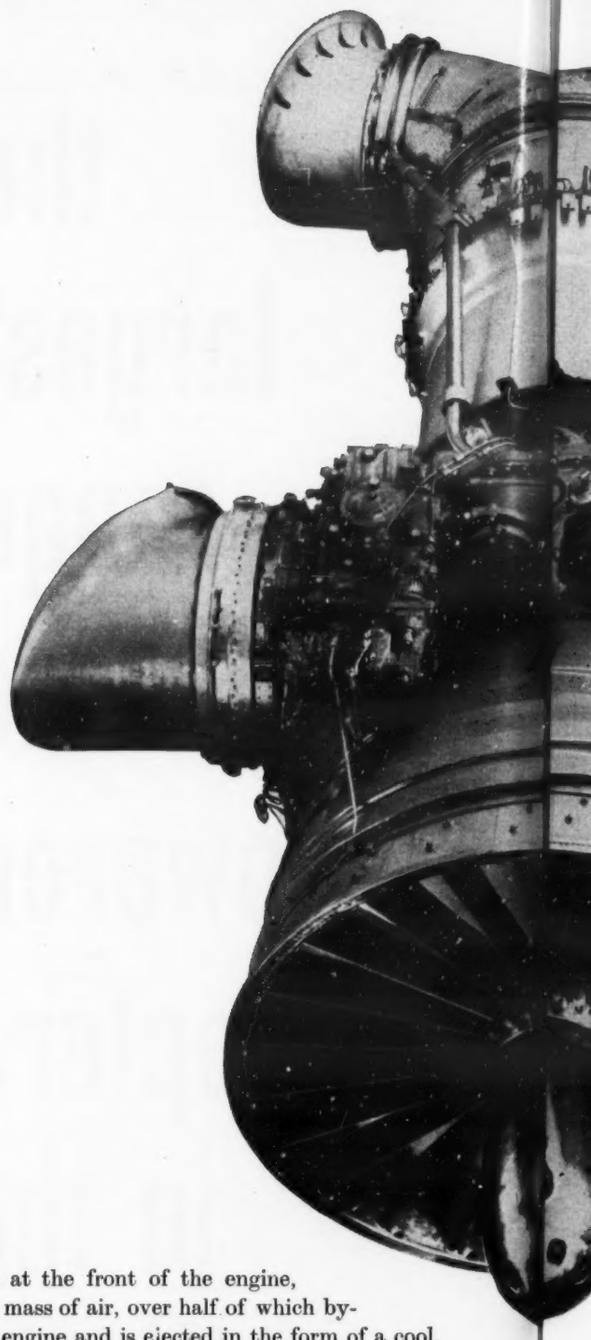
LIFT AND THRUST FROM ONE ENGINE



A single power source for VTOL and STOL aircraft. The new Bristol Siddeley BS 53 high-ratio turbofan is a major engineering breakthrough in the field of VTOL and STOL aircraft propulsion because it provides the airframe designer with a single power source *for all conditions of flight.*

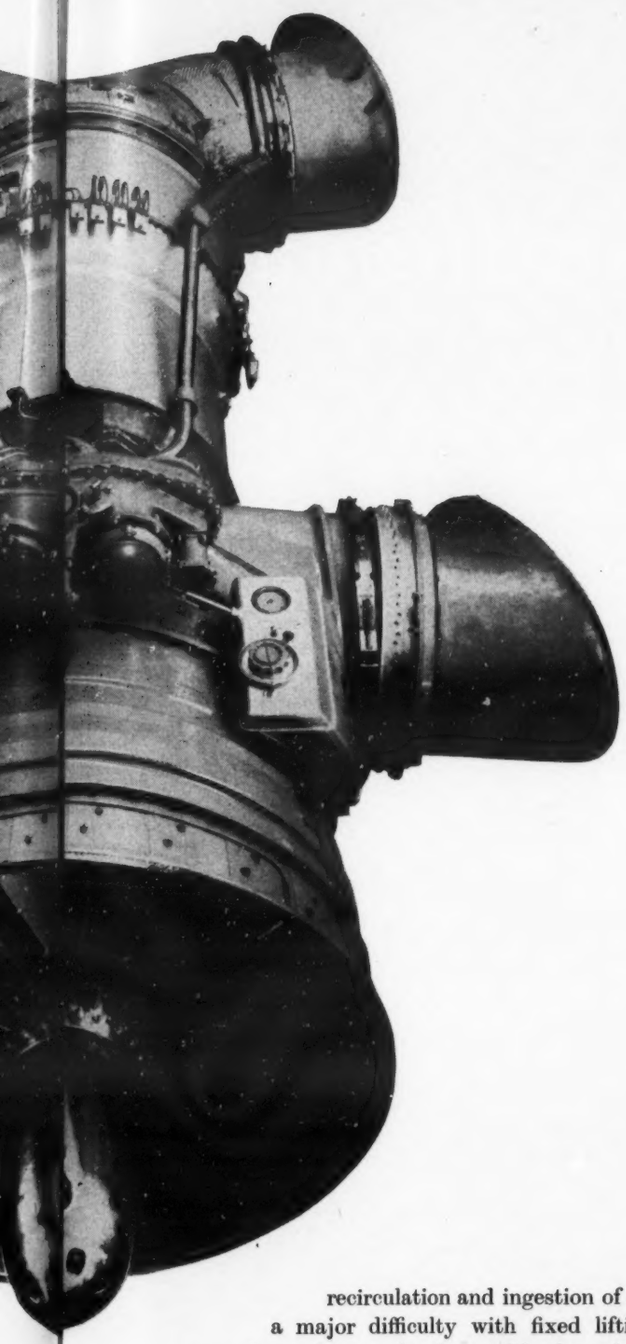
VTOL, STOL and normal take-off capability. The most revolutionary feature of this unique engine is that the thrust can be evenly applied around the centre of gravity through four movable nozzles which are directed downwards for lift, backwards for thrust, forwards for braking in flight, or in any intermediate direction. This makes possible, for the first time, the design of single or multi-engined aircraft in which the total installed thrust is available for vertical or short take-off with a normal payload or for conventional take-off with a large overload.

High cold-flow ratio, high thrust, low fuel consumption. The BS 53 is a high-thrust engine and the basic design concept which makes its versatile performance possible is a high cold-flow ratio.

A fan, located at the front of the engine, draws in a large mass of air, over half of which by-passes the main engine and is ejected in the form of a cool, relatively slow-moving stream through the two forward nozzles. The remainder passes through the gas generator and supplies thrust to the two rear nozzles. This arrangement greatly improves the Froude efficiency and gives the BS 53 a higher thrust/weight ratio, a lower specific fuel consumption and a lower noise level than any turbojet of comparable power in existence today.

Conventional installation, operational simplicity. The BS 53 is installed normally, with forward-facing intakes and the majority of its components are based on well-known principles already proved in service. These factors make for operational simplicity, easier maintenance, greater reliability.

Reduced problems of ground erosion and recirculation. Because the velocity and temperature of its jet effluxes are low, the BS 53 minimises the problems of ground erosion,



THE REVOLUTIONARY BS 53 TURBOFAN

recirculation and ingestion of debris which are a major difficulty with fixed lifting engines. All ground running can be done with the exhaust discharging backwards like a conventional turbojet. Taxying also is perfectly normal, and at take-off a short forward roll before the nozzles are deflected downwards ensures that all debris is left behind. As a result, the BS 53 does not require prepared sites and is *independent of all fixed ground installations.*

Selected for the world's first VTOL fighter. The Bristol Siddeley BS 53 has received the support of the Mutual Weapons Development Programme for NATO, and has already been selected for the world's first fixed-wing aircraft designed for operational service with V/STOL capability—the Hawker P 1127. Although this remarkable engine was primarily designed for this type of aircraft, it is equally suitable for any single or multi-engined, subsonic or supersonic aircraft which requires VTOL or STOL capability.

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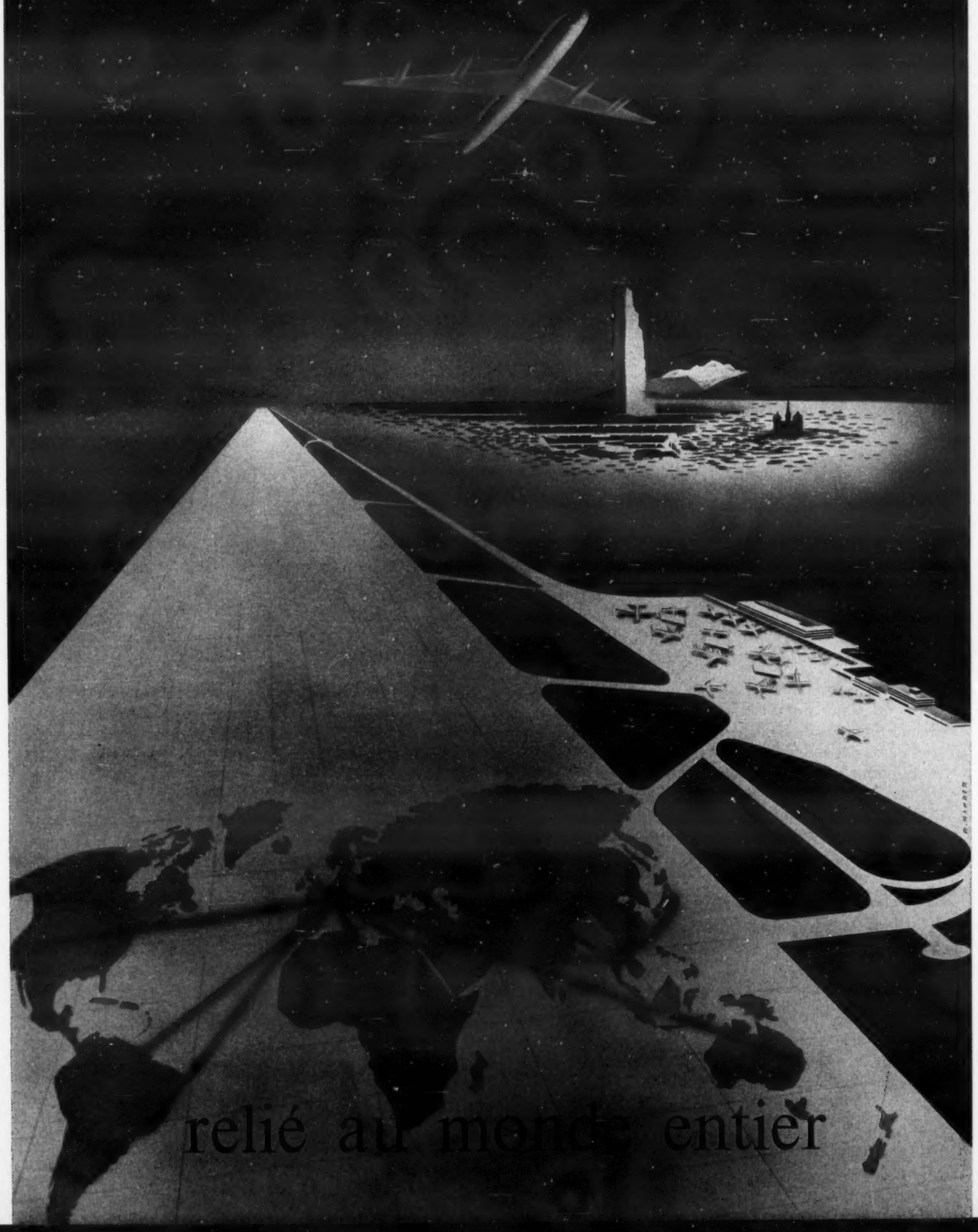
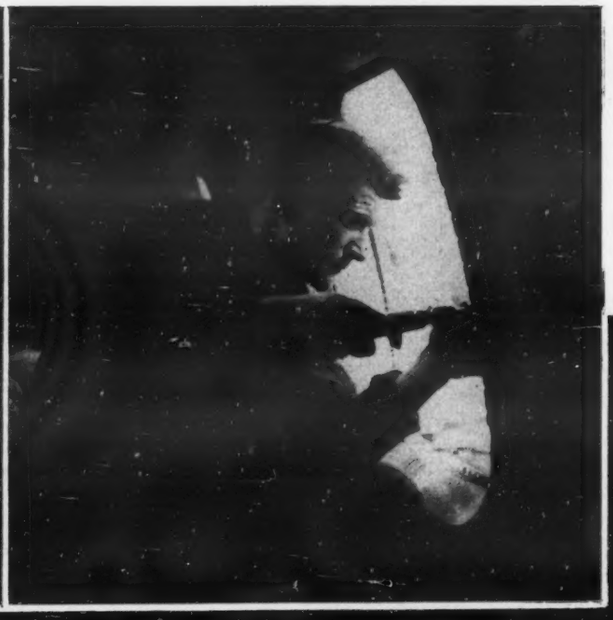


relié au monde entier



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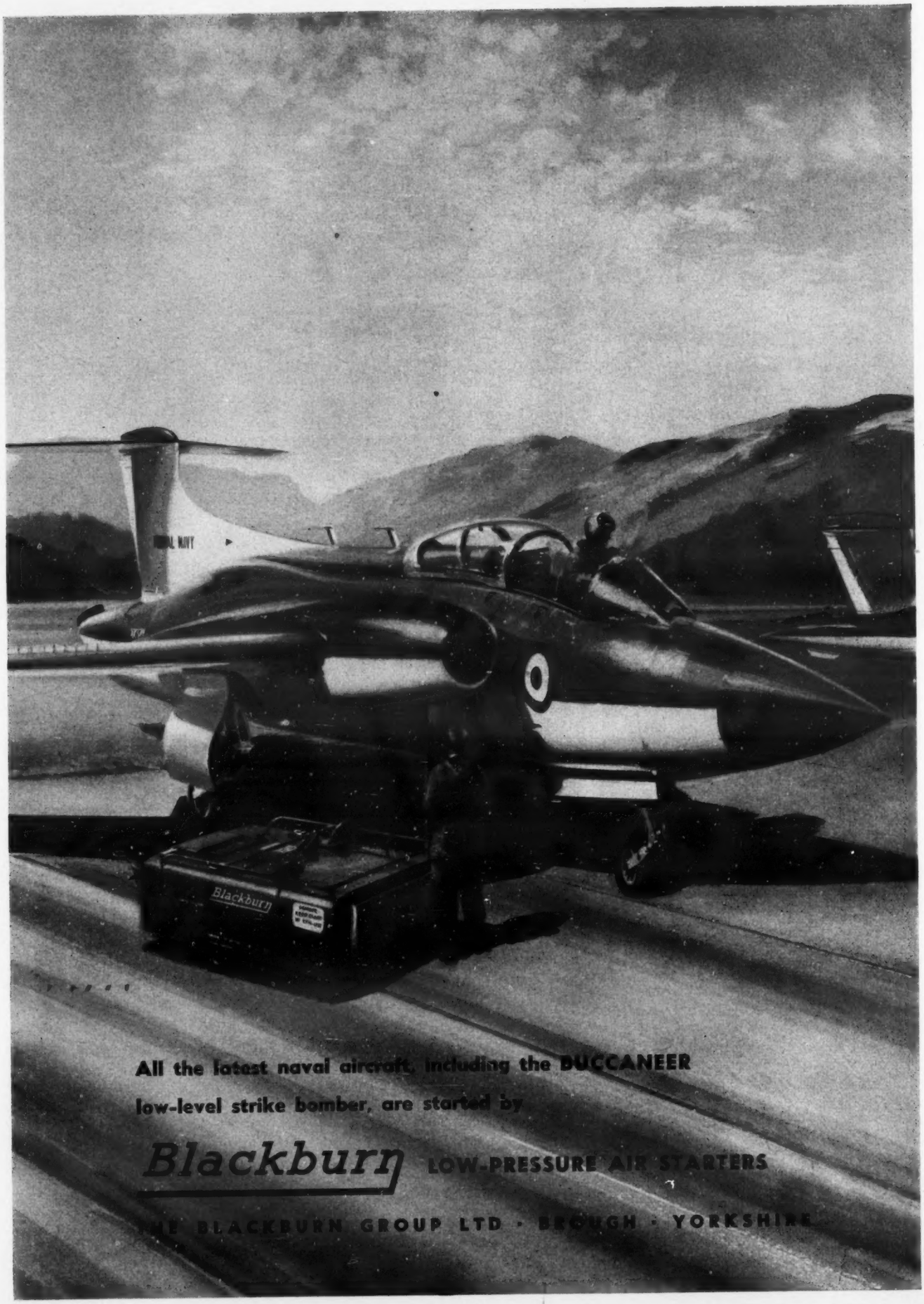

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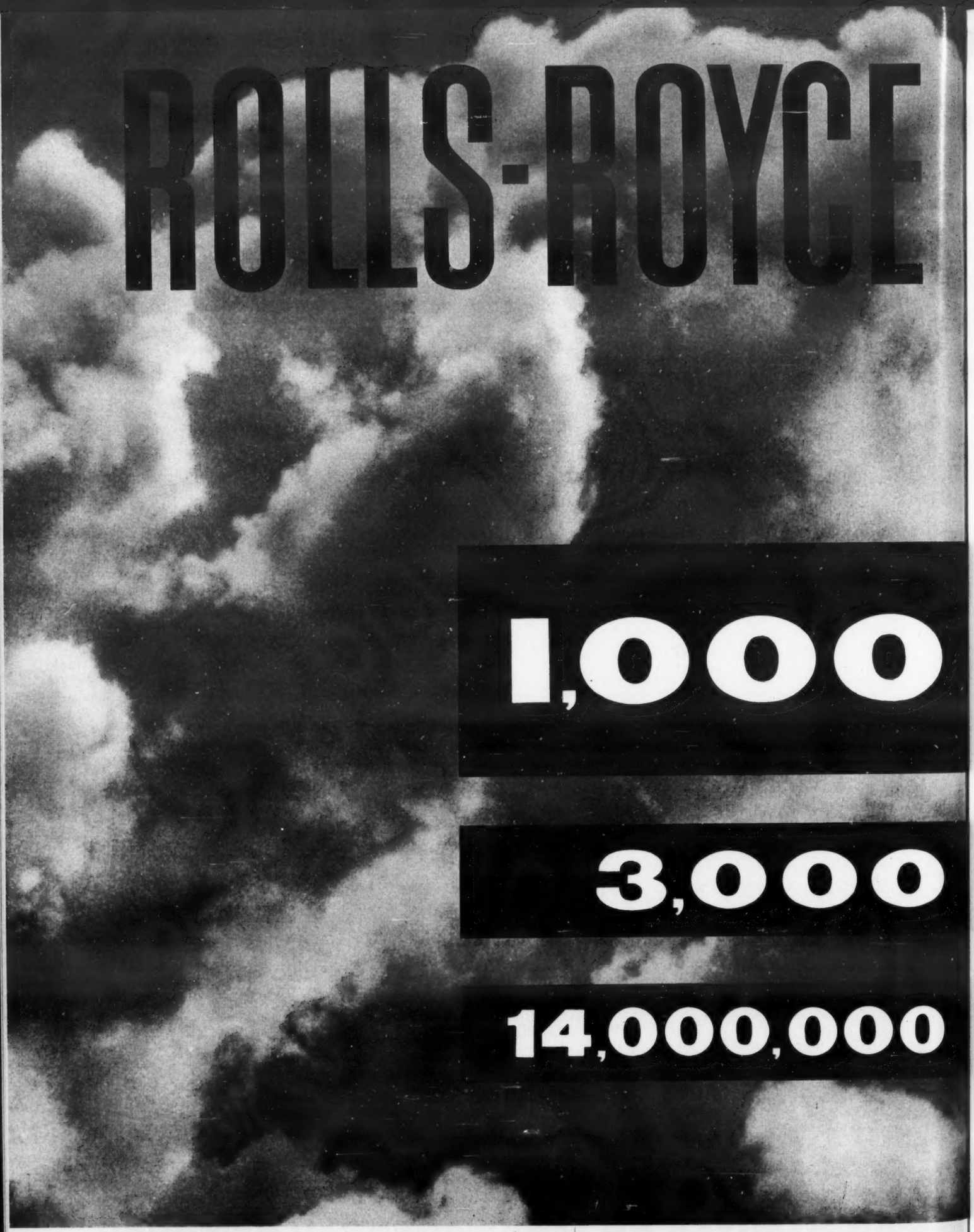
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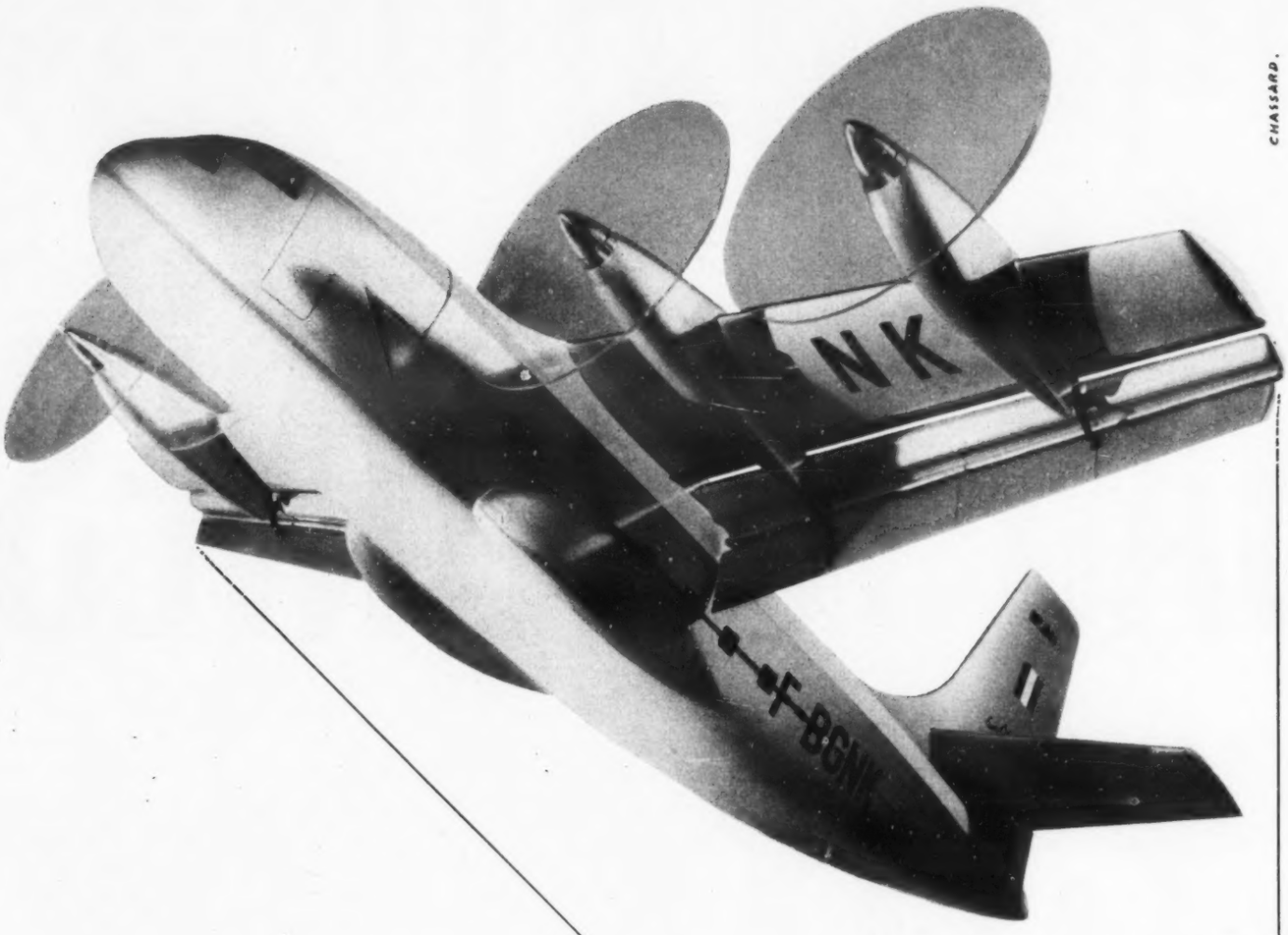

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THE SPEED OF A PHANTOM

* *This record was formerly held by a Russian T-405 at 1298.7 mph.*

** *This record was formerly held by a McDonnell RF-101C at 816.3 mph.*

The true value of a *combat* aircraft lies in the ability to *maneuver* at high speeds. On September 25 a Phantom II, piloted by U.S. Navy Commander John F. Davis, set a 100 km world closed-course record of 1390 mph.* flying a circular path less than 20 miles in diameter. On September 5 a Phantom II, piloted by U.S. Marine Lt. Col. Thomas H. Miller, set a 500 km closed-course record of 1216 mph.** flying a triangular course 310 miles in length.

Setting these records requires a much higher straight-line speed capability. Military security permits only the statement that maximum speed for the Phantom II is "in excess of 1500 mph."

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Farewell to Runways

There can hardly be a design office which has not sought a solution to the problem of short or vertical take-off. At the present time there are projects by the dozen, using all kinds of techniques; and aircraft firms have reached across frontiers and oceans to sign agreements which will enable them to make a more concerted attack on the VTOL and STOL markets.

Why is this so? What has spurred designers the world over to pass with one accord from oblique to vertical take-off?

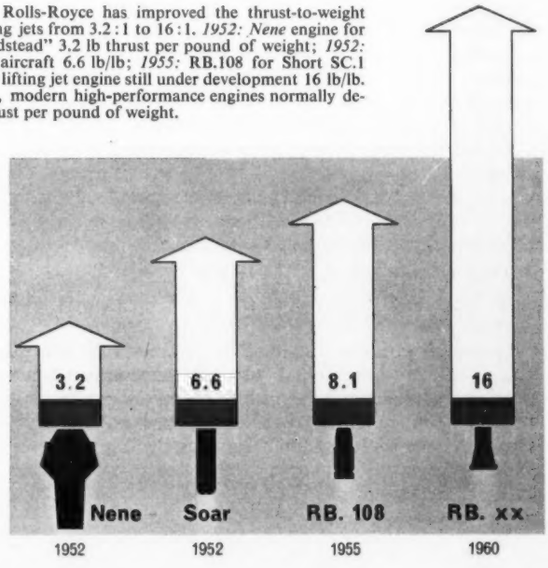
It is the Supreme Headquarters of the Allied Powers in Europe which deserves the praise for reviving a formula which the Americans had tried without success in the early fifties. At about the same time, SHAPE began to tackle the problem, but in a more modest way, restricting its demands to less prohibitive runway lengths than those required by the fighter-bombers at that time in service.

*

Although nuclear weapons have existed for the past fifteen years, and although it is not hard to imagine the devastation which would be caused by their use, it was only in 1954 that SHAPE was faced with the crucial choice between peace and atomic war; for the disproportion between the conventional forces in being would impose on the West the need to resort to weapons of mass destruction, whatever the type of conflict. Henceforward the armed forces would have to be adapted to face the conditions of a possible nuclear war; and the 10,000 ft runways, which had already been built in large numbers and were still under construction, must be abandoned. Laid down at the beginning of 1954, the Allied lightweight strike fighter specification stipulated that the runway length should be a mere 3,000 ft. The result of the specification was the Fiat G.91, which performs its missions to the satisfaction of its users. Barely was this aircraft on the drawing board, however, than SHAPE was already turning its mind to a second, and even a third generation. And last year a new set of specifications for a lightweight strike fighter, to operate from runways of roughly 1,500 ft, was drawn up and was the subject of a further competition between aircraft manufacturers. Designed for low-level operations from forward areas directly behind the first-line ground defences, such an aircraft would be particularly open to attack, and its role would be of short duration. It would therefore have to equip a number of units, be manufactured at moderate cost and require the minimum logistic support. SHAPE was setting its sights high in looking for an STOL aircraft which would fly at high subsonic speeds, be cheap to produce, and yet be capable of operating at very low levels under difficult weather conditions.

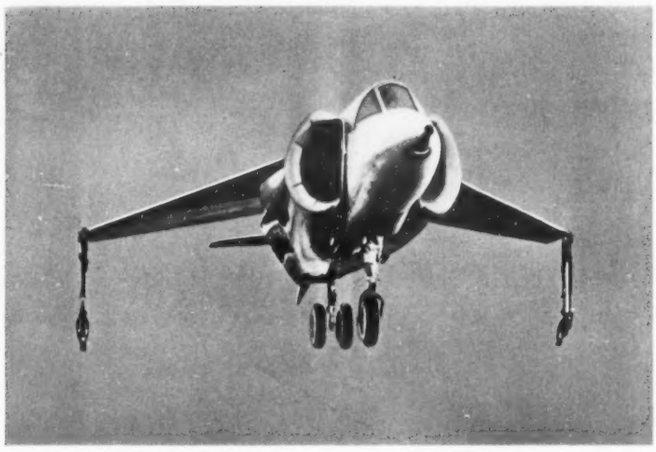
The discussions on the validity of the concept lasted for months. But in Britain work was going ahead. When, in 1956, the SHAPE specifications were laid before the Air Ministry, they were given a somewhat lukewarm reception. The SHAPE specifications as regards take-off distance and penetration speed appeared far too limited, for it now seemed that the ideas of a handful of British engineers were about to make the conventional aircraft a thing of the past. Short had for some time been using Rolls-Royce lift jets, and Bristol, working with the French engineer Michel Wibault, was carrying out research on the deflection and ejection of gases. The answer to the problem lay not only in a high thrust-to-weight ratio and in exploiting aerodynamic high lift devices, but in the use of new powerplants such as those devised by the Bristol and Rolls-Royce design offices. The former is staking everything on the high thrust of the by-pass engine, and on the simplicity and efficiency of a powerplant used for both forward propulsion and lift during take-off, landing and the transition phases. The latter firm, on the other hand, seeks to demonstrate the advantages of the composite system, with one engine for forward propulsion and ultra-light jets for lift. These are the two main concepts around which airframe manufacturers have designed their projects and built such promising prototypes as the Hawker P.1127 and the Short SC.1.

In eight years Rolls-Royce has improved the thrust-to-weight ratio of its lifting jets from 3.2 : 1 to 16 : 1. *1952: Nene* engine for the "Flying Bedstead" 3.2 lb thrust per pound of weight; *1952: Soar* for target aircraft 6.6 lb/lb; *1955:* RB.108 for Short SC.1 8.1 lb/lb; *1960:* lifting jet engine still under development 16 lb/lb. By comparison, modern high-performance engines normally deliver 4 lb of thrust per pound of weight.



*

But the original proposals issued by SHAPE defining the operational characteristics for NATO strike aircraft were soon to become outdated. Although in the United States the development of STOL techniques has mobilized enormous effort, barely 150 million dollars have been devoted to the corresponding military research during the past ten years. Until last year the U.S. Army was the only one of the three services which followed up the matter more closely. But next the USAF, too, entered the field with the requirement for an aircraft which would both make use of STOL techniques and be capable of very long-range operations. The USAF sought an aircraft which could be rapidly rushed to trouble spots and could make do with a limited ground organization in its zone of deployment, but which, taking off overloaded from a normal runway, could make the long flights across the oceans. The aircraft would be supersonic at sea level and would consequently fly at above Mach 2 in the tropopause.



Two British representatives of the VTOL formula: the Short SC.1 research aircraft (left) has four Rolls-Royce RB.108 engines for lift and one RB.108 for forward propulsion. During testing it proved itself fully controllable in all phases of flight, including the transition phase. The prototype of the Hawker P.1127 (right) has successfully passed its first vertical take-off and landing tests. This aircraft uses a single engine, the Bristol Siddeley BS.53, for both lift and forward propulsion.

As the demands on the pilot would be exceedingly great during low level operations in poor weather, the aircraft would be a two-seater.

This was a specification very different from that drawn up by SHAPE, for the Pentagon plans on a world-wide scale, while SHAPE is limited to the area of Western Europe and more precisely to an advanced line set up as near as possible to the Iron Curtain. Nevertheless, from the moment it appeared technically possible to reconcile very short take-off with flight at speeds well above that of sound, others wanted to follow the Pentagon's lead, and the second and third generations of NATO fighter-bombers were ousted to make room for the supersonic VTOL aircraft, with a higher weight but with a greatly extended range of combat roles. It was some months before SHAPE came to a decision. The small size of the European theatre, and the special nature of low-level armed reconnaissance operations meant that medium-performance materiel was adequate. But who can remain behind progress for long in the world of aviation?

After long discussions, the Allied experts opened the way for the supersonic STOL or VTOL aircraft. The British preferred to pass through the subsonic stage, with the Hawker P.1127 as the first standard operational aircraft of the new V/STOL generation. Britain's allies, on the other hand, saw the supersonic formula as a means of making up for lost time and catching up on the British designers. The French with supersonic projects worked out by Sud-Aviation and Dassault; the Germans with projects by Entwicklungsring Süd and Weser Flugzeugbau; and the Italians, also with supersonic projects, successively entered the new competition. European manufacturers have hesitated to follow the lead of American designers, who have daringly exploited the advantages offered by the variable-sweep wing, as in the Bell X-5 experimental aircraft. But since all wish their aircraft to be supersonic, they have chosen either a combination of lift jets (Rolls-Royce) and propulsive engine, or a new version of the Bristol BS.53 which will, when fitted with afterburners, provide sufficient thrust for flight in the region of Mach 2.

New links are, however, being forged every day between American and European firms: Boeing is considering deriving a "European" model from a project originally designed to satisfy American requirements, and Republic has announced an agreement with Fokker for the development of a VTOL aircraft to meet military specifications for the European theatre of operations (such an aircraft could have a variable geometry wing).

*

Although these designs have only just begun to take shape, the military experts are now considering supplementing the combat aircraft by a transport. A delegate at a SHAPE meeting remarked, and very rightly, that there was no point in building a combat aircraft capable of landing vertically in the heart of the jungle—or almost—if the pilot had to ask the enemy to bring him a ladder to get out. The question of the V/STOL freighter was thus brought up in the form of a witticism.

But neither the Pentagon nor SHAPE waited long before laying down the corresponding specifications. Generally speaking, the aircraft initially required must be capable of carrying a payload of 3 to 5 tons over a distance of 300 to 500 miles; it must have STOL or VTOL capabilities. A quantity which is still unknown is whether these aircraft will have propeller turbines and high lift devices or whether they will have lift jets, with priority being given to vertical rather than to short take-off. In Britain, thanks to the advances made in the field of lightweight lift jet engines, many designs already correspond to the performance required under the official specifications. It can therefore be seen that the VTOL combat aircraft will have a decisive influence on the transport aircraft, since only the second can solve the logistic problems posed by the use of the first.

*

The starting signal has been given, the race is open and the competitors are many, skilled and keen. Nobody, however, knows exactly where the techniques explored today will lead. Will the ground withstand the erosion effects produced by the effluxes from the vertical or oblique jet engines? What will be the effect of high temperatures, even for a few seconds, on the natural platforms used (say, a section of a road)? Will landings be carried out blind because of the dust raised? What will be the effect of ambient temperature on vertical take-off? Will a specialized ground organization be required, an organization which, however small, must be of none the less exceptional quality? Can the dispersal of combat aircraft which short or vertical take-off permits be reconciled with maintenance and operational requirements? Should lift engine techniques be combined with newer methods, such as increasing jet thrust or hot and cold flow mixing? Or is there a close link between the paths which airframe manufacturers are exploring today and those which the designers of ground effects machines have been following for some years? Are we faced with the choice between hot effluxes and cold air blowers?

Many more questions such as these will have to be answered. Nevertheless, the three armed services see the VTOL aircraft not only as an indispensable weapon, but also as an effective means of extending the useful life of the manned aircraft. Ground forces will add a third dimension to their operations, air forces will maintain their role, but will take off and land vertically, while in the navy aircraft will be able to take off and land from practically any ship, however small. The Liberty ship will be transformed into a floating base, carrying on its deck an aircraft capable of transporting atomic bombs to a target thousands of miles away. There is no need to stress the advantages of dispersing the destructive potential and the consequent high degree of security which would result from such a system. And this is the reason why the objections at present made on technical grounds will ultimately be swept aside. ←

Minimum-Field Aircraft

By Hawker Siddeley Advanced Projects Group

For the past few years it has been common practice to refer to an aircraft having a better than usual airfield performance as a short take-off and landing, or STOL, aircraft. Unfortunately there has been wide variation in the definition of "short" in this context; for instance, the U.S. Army definition is that the STOL aircraft must take off to 50 ft and land from 50 ft in 500 ft, whereas another point of view is that anything better than normal is STOL. This lack of unanimity of definitions has led to considerable confusion, not only in what is really meant by STOL performance, but also in what really constitutes a STOL configuration.

As an attempt at rationalization, it is proposed to use the general term "minimum-field" aircraft for that class of aircraft capable of taking off to, and landing from, 50 ft in less than 2,000 ft, a definition which encompasses all classes of aircraft from vertical take-off to rather specialized versions of conventional aircraft. In order to be specific the following definitions are used; as will be seen later, these roughly correspond to distinct categories of aircraft.

Airfield performance to and from 50 ft	*Definition*	*Abbreviation*
Zero ground run, vertical or near vertical flight path	Vertical	VTOL
Less than 500 ft	Ultra-short	USTOL
Between 500 ft and 1,000 ft	Short	STOL
Between 1,000 ft and 2,000 ft	Intermediate	ITOL
Greater than 2,000 ft	Normal	NTOL

There is a simple relationship between the airfield performance required and certain basic characteristics of the aircraft which will provide it. The most significant connection between the aircraft and its airfield performance is the minimum speed that can be maintained in level flight. The speeds associated with the above definitions of airfield performance are as follows.

Class	*Typical field length required*	*Minimum level speed (knots)*
ITOL	1,500 ft	60
STOL	1,000 ft	47
USTOL	500 ft	30
VTOL	0	0

The significance of the above figures is evident when one compares them with the stalling speed of, say, the *Viscount 800* series at maximum landing weight (about 88 knots) or that of the new Avro 748 (about 70 knots). Since the required lifting ability of the wing, at constant wing loading, increases inversely as the square of the minimum speed, it is apparent that in the "minimum-field" aircraft the lifting ability of the wing must be substantially increased, the wing loading reduced, or the aerodynamic lift augmented by some other means.

ITOL: Let us first take the aircraft capable of taking off to 50 ft or landing from 50 ft in 1,500 ft (with some allowance for engine failure and normal pilot scatter). This standard of performance could be achieved by conventional aerodynamic flaps, providing the wing loading was of the order of 30 to 40 lb/sq.ft. (as compared with the *Viscount 800* series at 70 lb/sq.ft.). If the wing loading is much higher than this figure, as may be required for optimum cruise efficiency or specialized military roles such as ground attack, then a very sophisticated aerodynamic flap system would be required, and it may be more advantageous to use some of the propulsive thrust to augment the lift either by blowing over the flaps or adopting the jet flap technique. Conventional, but powerful, aerodynamic controls should be adequate for this class of aircraft.

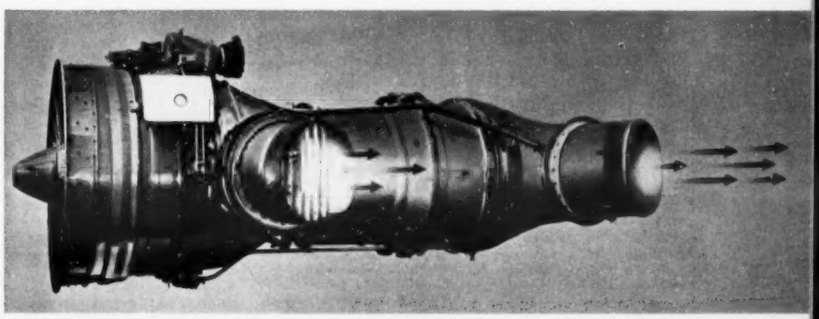
STOL: The ability to take off and land within 1,000 ft with allowance for engine failure and pilot scatter is even more demanding on the aircraft than ITOL performance, as indicated by the fact that the ratio of the squares of the minimum speeds is 0.6 : 1. This means that the wing must produce over 60% more lift at the same wing loading, or alternatively the wing loading must be reduced by about a third for the same lifting ability. Both these are unrealistic changes, and thus the STOL aircraft must resort to the third possibility, that of using some of the propulsive thrust to augment the lift.

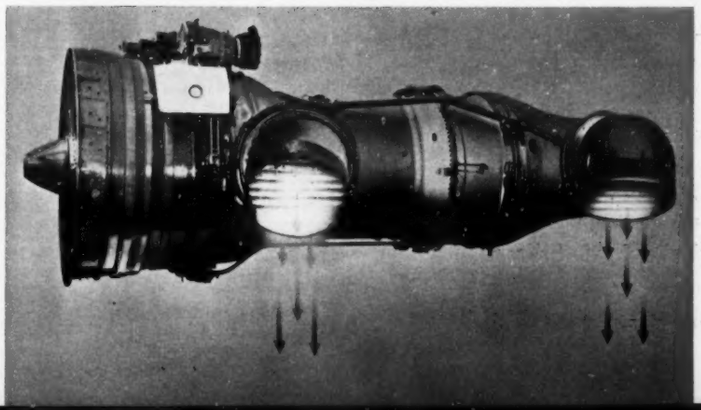
One possible solution for moderate wing loadings (less than about 50 lb/sq.ft.) is the jet flap, where high pressure air (either hot or cold) is ducted through the wing and ejected through a slot along the trailing edge. This method involves considerable structural complications, particularly if a hot jet engine efflux is used, and the control problems associated with very high lift coefficients may limit the amount of lift available unless some additional form of reaction control is provided.

A second alternative is to use a high-lift flap system to provide high aerodynamic lift, but to locate it in the slipstream of large propellers. In this way the velocity over the wing is increased by the slipstream, giving an increased lift coefficient; also the flaps deflect the slipstream downwards to provide a vertical component of thrust. In this way the lift available from the flap system alone can be increased in the ratio of about 2.5 : 1, but only at the expense of a large installed thrust-to-weight ratio of say 0.6 : 1, which is about twice to three times that of conventional aircraft. Furthermore, some additional control power will be required to augment that from the normal aerodynamic surfaces.

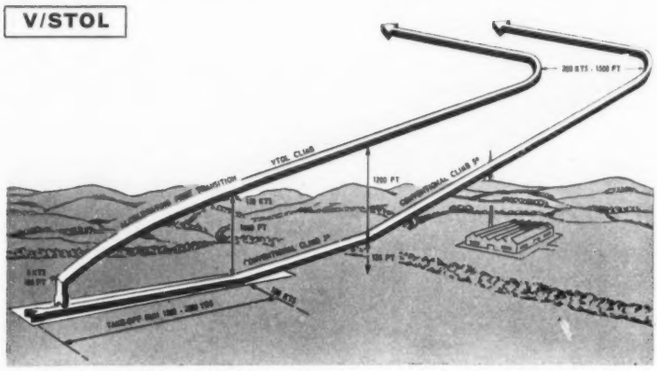
Summarizing, therefore, the STOL aircraft must use some of the propulsive thrust to augment the lift available from the wing and must also have additional control power. Both these requirements imply larger installed thrust/weight ratios than are usually provided, but this has a secondary advantage that, provided it is economically usable, the maximum level speed performance of such an aircraft is reasonably high.

USTOL: It is clear from the trends shown above that the USTOL aircraft requires an extraordinarily high lifting ability and/or deflected thrust, supplementary controls and a high installed thrust/weight ratio. The required values of these parameters do not differ greatly from those of an aircraft capable of taking off vertically, and it is therefore considered that USTOL perform-

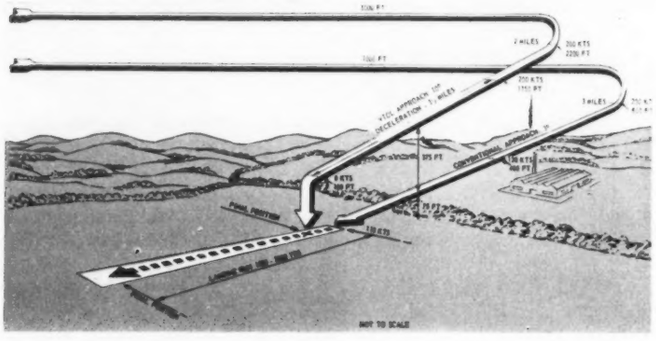




The operation of the BS.53 fan engine installed in the Hawker P.1127: During cruising, the hot and cold jet nozzles are rotated rearwards, so that the engine provides forward propulsion (upper picture). For take-off and landing the jets can be deflected downwards, so that the engine generates vertical lift (lower picture).



Comparison of the take-off path of a normal aircraft with that of a VTOL aircraft of the Short SC.1 category. The VTOL aircraft gains height more rapidly, obtaining a greater terrain clearance and, once transition is completed, generating less noise at ground level than the normal aircraft.

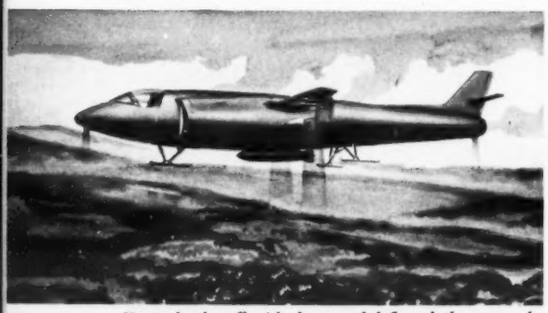


Comparison of the approach path of a VTOL aircraft with that of a conventional aircraft. The VTOL aircraft approaches the runway at a steeper angle, steadily decreases speed as it descends, and lands vertically on the ground. In poor weather conditions this method of landing is safer than the relatively fast landings of conventional aircraft.

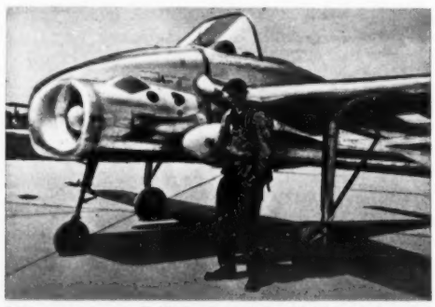
ance is merely an extension of the capabilities of the VTOL aircraft, making it possible to utilize a ground run and airborne distance of 500 ft either to carry a greater load or to reduce the thrust level and hence the noise. On this basis, therefore, it is considered that USTOL performance is entirely within the domain of the VTOL aircraft.

VTOL: The number of ways of achieving vertical take-off and landing has become incredibly large, and little purpose will be served here by attempting to describe them all. There are, however, certain basic factors involved in all the methods, and the most efficient combination of these factors is dependent upon the ultimate role of the aircraft. It is, therefore, of some interest to summarize the main parameters affecting the choice of configuration.

Firstly, the choice of lifting system is largely dependent upon the time that will be spent in the hovering phase. If a long period is required, as in the case of a flying crane for example, then the optimum method is one in which the hovering fuel consumption is low but the installed weight is high. This means producing the lifting force by a large mass of slow-moving air, and the helicopter rotor is a good example. If the hovering period is short, say 5 minutes, then it pays to reduce the installed weight by increasing the velocity of the air at the expense of fuel consumption. In this case a wide range of possible powerplants is available, and the ultimate choice depends on such factors as noise, compatibility with cruise efficiency, ease of changing direction of thrust, safety in the event of an engine failure.



Vertical take-off with downward-deflected thrust nozzles on the main engine: This VTOL low-level strike aircraft could be powered by an engine similar to the BS.53. The aircraft has very small wings, so that wing drag would be reduced greatly below that of conventional fixed-wing aircraft; performance would thus be improved, and the advantages of vertical take-off would be combined with increased speed and range.



Some years ago, Bell developed the X-14 experimental aircraft, powered by two *Viper* jets fitted with thrust deflection devices enabling the X-14 to take off and land vertically in a horizontal attitude. This aircraft was the forerunner of the line of development which Bristol Siddeley represents today, where the same engine serves to generate lift and forward propulsion.

Probably the best way of indicating how such factors are combined is to describe briefly two or three different types of VTOL aircraft that are either projected or being produced.

1 - High subsonic fighter/tactical strike aircraft

The problem here is to obtain the greatest installed thrust with the minimum installed weight and volume; this suggests the use of the same powerplant for both lift and propulsion. Safety after an engine failure, or noise, are not of paramount importance. One solution, as typified by the Hawker P.1127, is to use a single lightweight ducted fan engine producing thrust from four nozzles that can be conveniently disposed about the aircraft centre of gravity, and can be easily rotated from the vertical to horizontal. This arrangement is probably the most economic yet devised and combines a reasonable hovering efficiency with moderate levels of noise and ground erosion; however, it depends largely on the fact that the P.1127 is a military aircraft, and a single engine is acceptable. It is unlikely to be the best arrangement for a civil transport.

2 - Subsonic military transport

Here the problem of safety after engine failure cannot be disregarded. This means multiplicity of lifting units. Noise is not of great importance, but installed weight and volume are. Very high forward speeds are not really required, and the optimum lift and propulsive power systems have somewhat different characteristics. A very attractive solution therefore is to use a conventional low-consumption propulsive system, such as a propeller turbine, and provide a separate lifting system with a large number of very light, high-velocity jet engines.

3 - Subsonic civil transport

The problems here are similar to those of the military transport, with the exceptions that noise level at take-off and landing must be low, and cruising speed as high as possible. These additional requirements point to the use of turbofans for lifting and high-efficiency turbojets for cruising. A combination of propulsive turbojets with augmentation fans for vertical lift seems attractive, providing the installation problems can be overcome. (The *Rotodyne* is an example of this principle, but the rotor seriously restricts the forward speed.)

It is emphasized that the above are only typical examples, as there are many ways of doing each particular job.

Military applications

We now come to the question of the future outlets for "minimum-field" aircraft, starting with the military sphere. A major consideration in assessing the potentional of any airborne vehicle is the nature of the terrain from which it is intended to operate. For instance, in civil operations, "minimum-field" aircraft could be used from fields that are at present far too small for conventional aircraft. In the military sense, however, the case is somewhat different, since one of the major arguments for the "minimum-field" aircraft is its ability to operate from more-or-less unprepared fields, either in "colonial" territory or in the event of a "hot" war where conventional airfields may be destroyed in the early stages. It is important, however, to be reasonably specific in what is meant by an "unprepared" field. For instance, is the "unprepared" field covered by boulders? If so, how big is a

boulder? Or if it is muddy, how deep or how sticky is the mud? However, it is assumed here that the unprepared field is a reasonably level field with earth or sparse grass surface and does not contain ditches, tree stumps or other large obstacles. This definition is in line with the assumptions made in a study by the U.S. Army.

In the military sense, the ultimate need for VTOL, USTOL or STOL capabilities is very largely dependent upon the particular mission associated with the aircraft. Vertical capability is essential for army reconnaissance, flying cranes, rescue aircraft and possibly front-line communications aircraft, but the importance of VTOL decreases and is replaced by STOL performance in the cases of observation aircraft, forward area transport and close support fighter or strike aircraft. The importance of STOL performance then begins to diminish, and intermediate or normal airfield performance is acceptable for communications aircraft, rear area transports, intertheatre transports and conventional strategic bombers. It is of interest to note that the nearer the operating base is to the front line, the more important becomes the ability to operate from short or zero length airfields.

It appears that the aircraft of direct interest can be grouped into four distinct categories, as follows:

1. Close support fighter/strike/reconnaissance aircraft
2. Assault/forward area transport
3. Front-line communications/observation aircraft
4. Communications aircraft.

Very real contributions may be made in each of the above four spheres by introducing "minimum-field" aircraft techniques. This is already being done, of course, in the case of the Hawker P.1127, which represents an example of the tactical strike/reconnaissance aircraft of category 1 with full VTOL — STOL capabilities.

In category 2, several missions might be combined in one aircraft, the difference between an assault transport and a forward area transport possibly being the degree of overloading permissible within the range of VTOL to STOL performance.

As regards category 3, at the present time air forces and armies use conventional lightweight aeroplanes for observation and front-line communication duties. By virtue of their very low wing loading, these aircraft have airfield performance within the meaning of "minimum field," and it is not really the purpose of this paper to discuss their ultimate replacement.

The fourth category includes the communications aircraft, and here it would appear that there is a very real need for new aircraft to replace the twin-engine types in current use by various air forces.

The airfield requirements of a new communications aircraft are not entirely clear at the present time, and although it may be argued that the ultimate communications aircraft should have vertical take-off and landing capabilities, the expense of such a system and its possible conflict with the obvious requirements of high forward speed may rule out VTOL. Possibly a more profitable line is an aircraft having STOL performance, say of about 1,000 ft, coupled with a high subsonic cruising speed. The "jet-flap" scheme seems to be particularly applicable here.

Civil applications

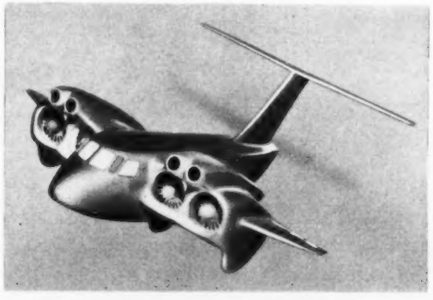
In the civil domain, the case for "minimum-field" aircraft is much less clearly defined, since the civil operator is not fundamentally concerned in operating from unprepared fields. By its very nature, civil air transportation requires a rather complicated ground organization, and thus existing airfields are of more interest. There appear, therefore, to be two main areas to be filled by the civil "minimum-field" aircraft: these are the genuine city-centre, to city-centre, or centre to international airport services, and the capability of extending routes by using airfields at present too small for conventional passenger-carrying aircraft. The private personal aircraft is in rather a different category, as it must be as cheap as possible, and it is generally true that the means of obtaining "minimum-field" capabilities are all expensive, with the exception of low wing loading. This class of aircraft has already been extensively exploited by manufacturers in the U.K., USA and Europe.

It appears that there are considerably fewer categories of "minimum-field" civil aircraft, and they fall into more clearly defined groups than the military machines.

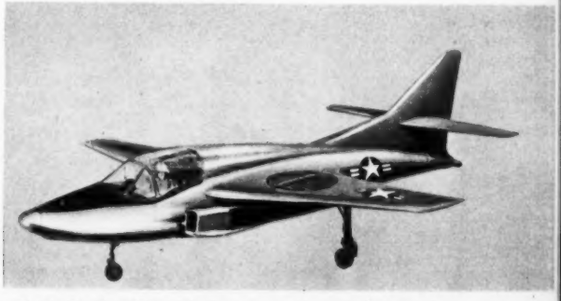
For instance, the aircraft operating from city centres must almost certainly have full VTOL capability, and the helicopter is the present (and possibly the ultimate) solution. However, an intercity aircraft which normally operates from USTOL fields of say 500 ft but which has a VTOL capability at reduced weight may be a useful alternative. The private personal, "bush" and agricultural aircraft require good airfield performance, but must be cheap to buy and operate; consequently it seems that if VTOL is essential then the helicopter, which already exists in quantity, may be the correct choice, although not cheap. If VTOL is not essential, then the conventional solution of a very low wing loading is probably the cheapest.

The only other aircraft having any immediate call on minimum-field capabilities is the domestic airliner for secondary routes, i. e., one which opens up a network by using existing small fields. To choose the desired airfield performance, we should investigate the various airfield lengths available. The results are rather remarkable. Of the 180 airfields in the U.K., 167 (93%) are longer than 2,000 ft, six (3.3%) are between 1,500 and 2,000 ft and five (2.8%) between 1,000 and 1,500 ft; there are none less than 1,000 ft except two heliports which come into the 0 to 500 ft bracket. The figures for Europe are similar, and of the total of 642 the following distribution is found:

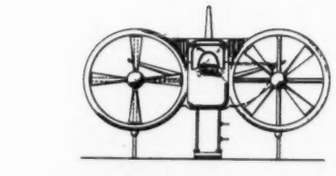
Short take-off by downward deflection of the slipstreams of ducted propellers: Piasecki Aircraft Corporation describes its ring wings fitted with deflector flaps and propellers enclosed by the wings as an "integrated propulsion and lift system." The "ring-wing" project, developed under contract to the U.S. Navy's Bureau of Aeronautics, has conventional control surfaces at the tail and a control nozzle with deflector plates (also at the tail) to improve controllability during hovering.

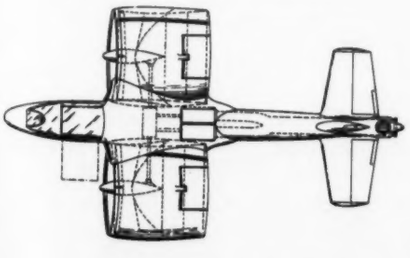


Short and vertical take-off by downward deflection of turbo fan airstream: The four Pratt & Whitney J60 jets of this highly individual Chance Vought project drive four turbofans via separate turbines. The airstream generated by the fans can be deflected downwards, enabling the aircraft to take off and land vertically.



Vertical take-off by lift fans mounted in the wings: A General Electric Company proposal for a photographic reconnaissance aircraft, powered by two GE J85 turbojets and two jet-powered lift fans in the wing roots to give the aircraft VTOL characteristics.





Factors governing choice of VTOL configuration

Requirements	Cruising efficiency		Low noise level when hovering	Hovering efficiency		Safety
Defined by	Max. miles per lb of fuel at high forward speed for min. weight of powerplant		Lowest practical noise level and min. ground erosion in hovering	Min. weight of fuel and lifting system. Fuel dependent on efflux velocity		Ability to continue take-off after failure of single unit with min. installed lift-to-weight ratio
Explanatory diagrams	A		B	C		D
Solutions	Low speed less than 400 knots Turboprop	High speed greater than 400 knots High by-pass turbojet or normal turbojet	Rotor or fan for hovering phase Efflux velocity 600—1,000 ft/sec	Noise important Ducted fan with efflux velocity 600—1,000 ft/sec	Noise not so important Lightweight jet engine efflux velocity 1,600—2,000 ft/sec	Not less than 8 engines. Less than 8 requires large lift margin. Large number means increased complexity. Lift should be as near centre of gravity as possible.
Applications	Military transport	Civil airliner Military transport	Civil airliner Military transport	Civil airliner Military transport	Military transport	Civil airliner Military transport

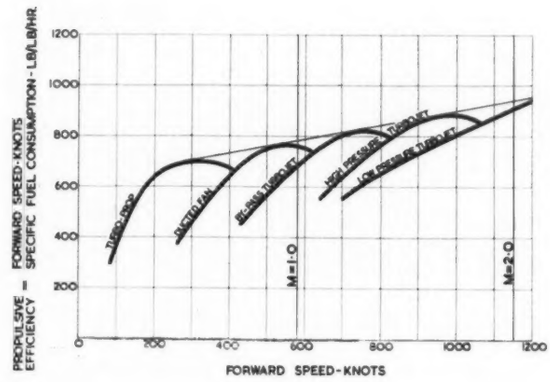


Diagram A

Variation of propulsive efficiency with forward speed. The propulsive efficiency, or the relationship between forward speed and specific fuel consumption, is shown plotted against forward speed. As the diagram shows, each of the five engine categories works with optimum economy only in a given speed range.

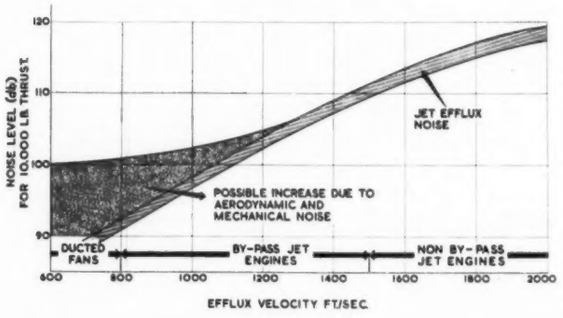


Diagram B

Noise rating for 10,000 lb thrust level at 800 ft slant range. The noise level in decibels is shown in relation to increasing jet efflux velocity. It is lowest for the ducted fan engine, reaches moderate values for conventional by-pass engines and rises to almost 120 db for straight jet engines.

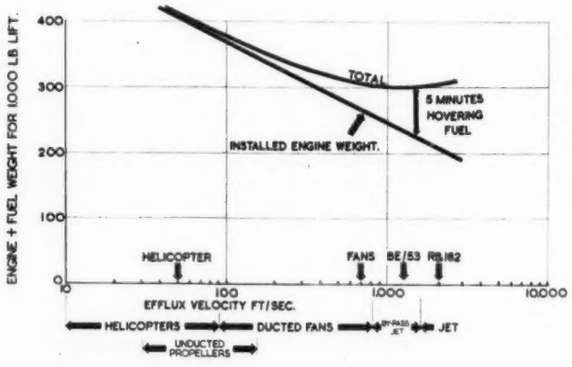


Diagram C

Relative weight of installed power system plus fuel for hovering. The engine installed weight and the weight of the fuel consumed during hovering—for each pound of lift—are shown in relation to the efflux velocity in ft/sec for helicopters, unducted propellers, ducted fans, by-pass jets and jets. The solid curve indicates the total weight of engine plus fuel consumed during five minutes' hovering.

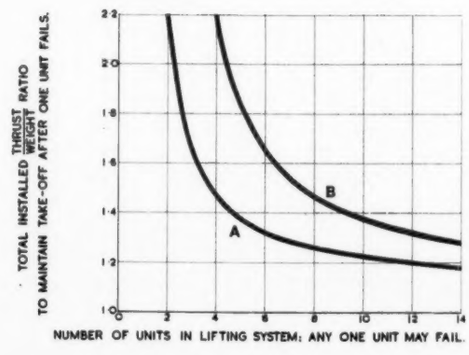


Diagram D

Variation of required thrust/weight ratio with number of units in lifting system. The two curves, representing failure of a single unit (A) and shutdown of second engine to prevent asymmetrical thrust (B), indicate the thrust/weight ratio with which it remains just possible to continue take-off after an engine has failed.

Over 2,000 ft	534	(83.2%)
1,500—2,000 ft	81	(12.6%)
1,000—1,500 ft	16	(2.5%)
500—1,000 ft	7	(1.1%)
less than 500 ft	4	(0.6%) (probably all heliports)

It does not therefore appear possible to obtain a substantial increase in the U.K. route networks by producing a specialized "minimum-field" aircraft with, for instance, a 1,000 ft capability, since this would only bring in a further 11 airfields (6.5%).

There is, however, a possible alternative which may show up to advantage here. This is basically a "minimum-field" aircraft which also has the ability to operate from conventional fields at higher weights, and hence with better economy. The jet-flap aircraft appears to have this ability.

The picture in Europe is slightly different, as a 1,000 ft capability would introduce 97 (15.1%) more fields, but of course the desirability of including such fields in an operational network cannot be assessed here.

City-centre operations: The above indicates very little potential for the specialized "minimum-field" civil aircraft for secondary routes. The alternative is the genuine inter-city transport, and we must investigate other "open" areas that are available close to city centres and to amenities such as passenger-handling facilities. The first obvious choice here is the main-line railway stations, which already occupy considerable areas of ground, produce fairly high noise and other nuisance levels, already have passenger-handling facilities and are reasonably conveniently sited for centres of business and population. These stations already have large areas covered by high roofs, and a superstructure built on top of a railway station may provide a good take-off and landing platform for V/STOL civil aircraft.

One of the biggest problems is noise. If the aircraft is to operate from city centres, then it is obvious that it must not cause noise very much greater than is at present experienced in the cities—certainly much less than is caused by present large jet transports.

Present data indicate that with pure turbojet engines the VTOL aircraft will have excessive noise levels for city-centre operation. Even the use of turbofans, with their reduced efflux velocity, does not appear too promising as their level appears to be at least 10 db too high. Thus noise considerations may rule out jet-lift VTOL

aircraft from the very operation that seems to be made for them, and it is still not clear that the noise of the tilt-wing aircraft can be reduced to acceptable levels for the city-centre operation. This may be a pessimistic outlook, since a large amount of effort is being expended on the subject of noise reduction for conventional aircraft, and this work may produce breakthroughs that are equally applicable to the VTOL aircraft. Against this it must always be remembered that the VTOL aircraft needs three to four times the installed thrust of a conventional aircraft, and thus its noise problem is more acute from the outset.

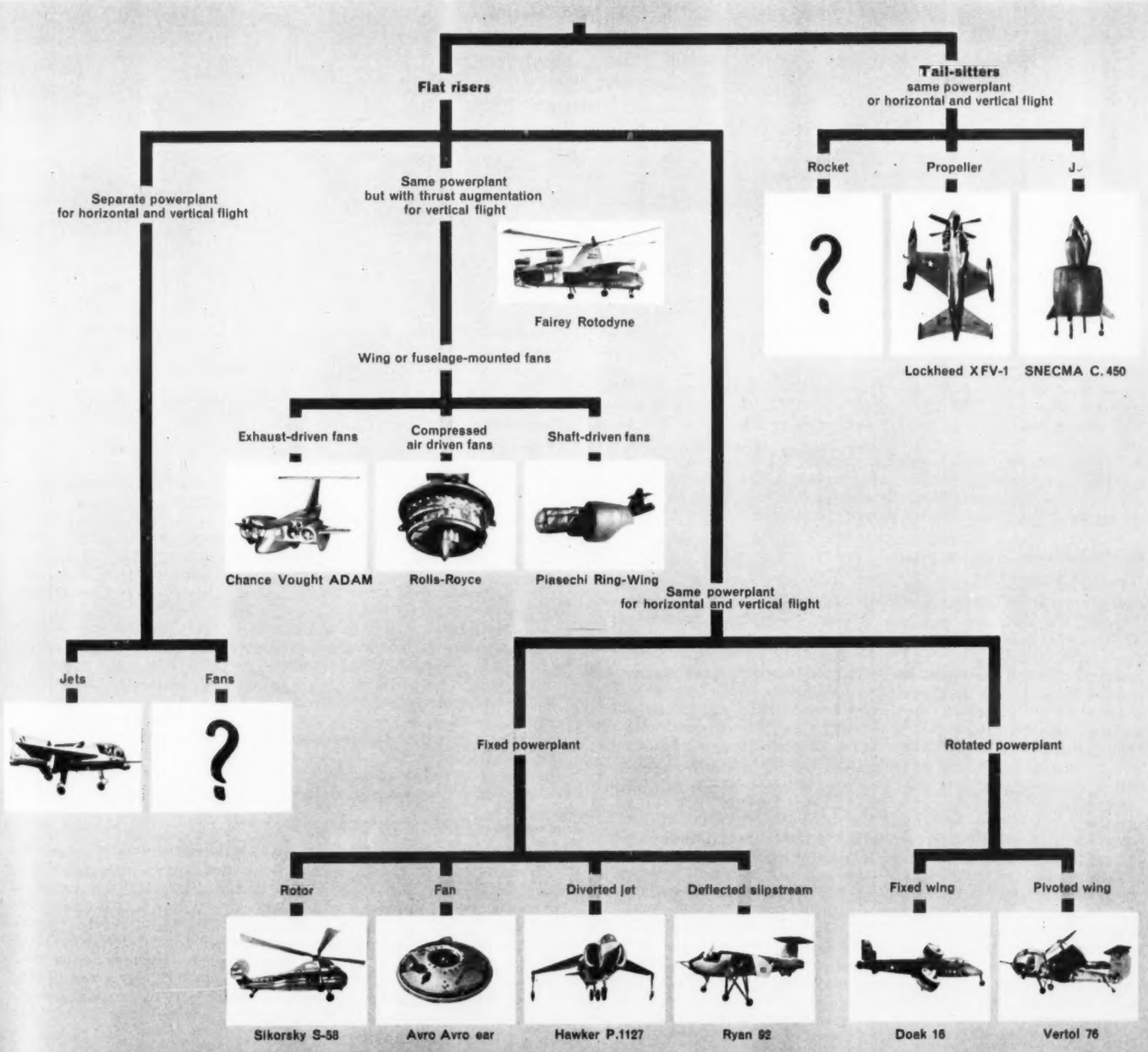
VTOL supersonic transport: No mention has yet been made of another application of "minimum-field" techniques to civil aircraft, the VTOL supersonic transport. This subject has been discussed in public at some length, principally by the engine manufacturers, and claims have been made that by adopting VTOL techniques it is possible to reduce very considerably the size and operating cost of a supersonic transport. This claim remains to be substantiated, and present investigations indicate that the opposite may well be more realistic. A VTOL supersonic transport may weigh some 50% more than the conventional aircraft for the same job. Whether the inherent advantages of VTOL are sufficient to offset this large increase in size, weight and cost, particularly since existing runways are adequate for projected conventional take-off supersonic transports, cannot be discussed here.

There is, however, a possibility that if the cruising speed of future supersonic transports reaches the M = 3.5 to 4.0 region, then the difficulty of providing adequate airfield performance, especially an acceptable approach speed, may be very great, and the use of lifting engines may then be the simpler and more economic method. Such aircraft are, however, probably beyond the first-generation supersonic transports. Furthermore, the airworthiness and air traffic control problems arising from the civil operation of large VTOL aircraft are prodigious. Without doubt the airworthiness authorities and the airlines will require some vehicle less sophisticated than a supersonic transport to gain the essential operating experience in the new techniques involved in vertical take-off and landing.

Economics

The economics of "minimum-field" aircraft in city-centre operations are too complicated to assess in a general manner. The two important parameters appear to be firstly, the increased convenience of the service, which could lead to much higher load factors than are achieved by conventional aircraft operating from large airports some distance from centres of population and business, and secondly, the undeniable fact

VTOL family tree



that a "minimum-field" aircraft will be more expensive to operate per seat-mile than its conventional counterpart.

The time saved by the ability of the VTOL aircraft to operate from the city centre is very significant. If we take the London to Paris route as an example, and consider the time taken from city centre to city centre, then we find the conventional *Viscount* cruising at about 300 knots has a total journey time of 3 hr 10 min, i.e., 40 min passenger-handling time at the airports plus 1½ hours ground transit time, plus 1 hour flying time. The increased speed of, say, the *Comet 4* of 450 knots reduces the total time by only 12 min, to 2 hours 58 min. Assuming that the VTOL aircraft takes off and lands at the bus (or rail) termini, then the total time taken by an aircraft having the same cruising speed as the *Viscount* is 1 hour 28 min, i.e., 1 hour 42 min less than the *Viscount*.

It is difficult to generalize on the direct cost of operating subsonic VTOL transports, but it is possible to formulate a few basic principles. Firstly, the installed powerplant weight is much larger (3 times) than that of a conventional aircraft, and consequently the first cost of the powerplant is greater for the same job. This increases the amortization and insurance costs, and repair and maintenance costs. Secondly, the fuel required for the same job is greater than that for the conventional aircraft, and the fuel costs are proportionately higher. There is a small difference in the block speed from take-off to landing point between VTOL and conventional aircraft, and consequently the fixed costs such as crew pay etc. are relatively of the same significance. In the balance, it appears unlikely that the direct operating cost of the VTOL aircraft can ever approach that of the conventional aircraft doing the same job at the same forward speed. Design studies have indicated that the VTOL figures are of the order of 60 to 100% higher than those of the conventional aircraft.

Of course, direct operating costs are not the whole story, and at present the direct cost is only 40 to 50% of the total cost. If the indirect costs remain unchanged, then the total operating cost of the VTOL aircraft will be only 30 to 50% above that of the conventional aircraft and slightly less than this if the cost of ground transport is included in the cost of the conventional journey.

Taking a broad look at the future, it is not unreasonable to assume that the fare for a short-range subsonic VTOL aircraft may be 20 to 30% greater than that for the conventional aircraft, but this must be offset against the tremendous saving in time obtained by eliminating the ground journeys to and from the air termini. →→

The Tactical Combat Aircraft: Towards Total Mobility

by General L. M. Chassin (Ret.), Paris

Following the Farnborough demonstration of the Short SC.1, the Hawker P.1127 has now completed the first series of trial flights, both free and tethered. In these two aircraft we have the first European exponents of vertical take-off, each representing different approaches to the problem. Many others will follow. We are now approaching—faster than many people thought possible—the total mobility of aircraft; they are no longer prisoners of runways and supply points, which in their complexity and huge dimensions mean death and destruction to their users in time of war.

This is not to say that the problem of mobility has been solved. On the contrary, constructors and military planners have still to overcome problems of immense difficulty, and since the coming of age of the atomic weapon the extent of these problems has become greater than ever.

Survival through movement

The great strides made in the development of weapons of attack have utterly altered the traditional concept of defence: geographical distance, dispersal, and protective structures. In view of the greatly increased range of the atomic bomb carrier—be it missile or aircraft—distance no longer gives protection, even to the United States. Moreover, the destructive power of the new explosives makes dispersal unrealistic, as long as the attacker has a sufficient number of bombs at his disposal. As far as protective installations are concerned, their utility is not wholly lost (deeply-placed subterranean installations are still useful, but they demand extensive planning, and costs are extremely heavy), but they are much less suitable as a defence against atomic weapons than their predecessors.

It is obvious that defence must strike out along new paths, develop new methods, and in the language of the military academies, as defined by General J. F. C. Fuller, follow the "tactics of ever-changing position." In other words, constant movement means survival. We must never be where the enemy expects us to be. Under no circumstances must aircraft return to their original bases; they must always land on other sites. Obviously, all of the supply points must be provided with the essentials of modern war: fuel, munitions, and maintenance equipment, all of which constantly become more complex and more extensive. Our only consolation is that an atomic war is likely to be of short duration.

As long as aircraft require huge airfields, even though they may be of the semi-prepared type, a genuine and successful tactic of movement is unthinkable. But when vertically starting and landing aircraft are available, then matters appear otherwise. It is necessary only to come to agreement over the functions of the new aircraft, and then to draw up appropriate specifications for it.

Essentially, VTOLs can undertake any sort of mission. But they are best suited, as has been shown, to operate as successors to the well-known low-level NATO Fiat G.91 fighter or the Etendard IV M employed by the French Navy.

Requirements of a theatre of war

An aircraft must not only possess the requisite capabilities for the missions on which it is committed, but must also be adapted to the theatre of war in which it will be employed. If it is to operate over the great spaces of the Pacific, for instance, then everything depends on its range. On the other hand, if it is to be used in the narrowly confined European theatre, the strip between the Iron Curtain and the Atlantic, then it requires other qualities: fast rate of climb, suitable speed at low and high altitudes, proper armament, etc. In other terms, Europeans can build significantly lighter aircraft than are built on the other side of the Atlantic. These considerations apply specifically to VTOLs.

The reservation must here be made that should an attack have to be delivered against a very distant target, possibly in Siberia, then an aircraft starting on its mission from a Western European base must possess the proper range (this necessity renders difficult the creation of certain types of deterrent forces). But for a limited atomic conflict such considerations need not be taken seriously. Of course there is a possibility that there will be neither a limited nor a global atomic war. It is also possible that a limited war would soon extend itself, becoming a total atomic conflict. However that may be, NATO strategists are of the opinion that it is high time to prepare for the worst and make ready a VTOL as a successor to the G.91.

Missions

What is an aircraft of this type to do? Although no official programme has been published, or even decided upon, technical journals, particularly *Interavia* (Nos. 5 and 7/1960), have discussed this question in detail, so that a certain number of conclusions may be drawn. It is known that Sir Harry Broadhurst, Chief of AIRCENT (NATO Air Forces, Central Europe) evolved this programme and arranged for its submission to the governments of NATO countries, which made certain alterations to it. After the programme has been submitted to NATO's Permanent Military Committee and approved, member countries will be recommended to procure suitable aircraft. It is of course hard to predict what will happen if

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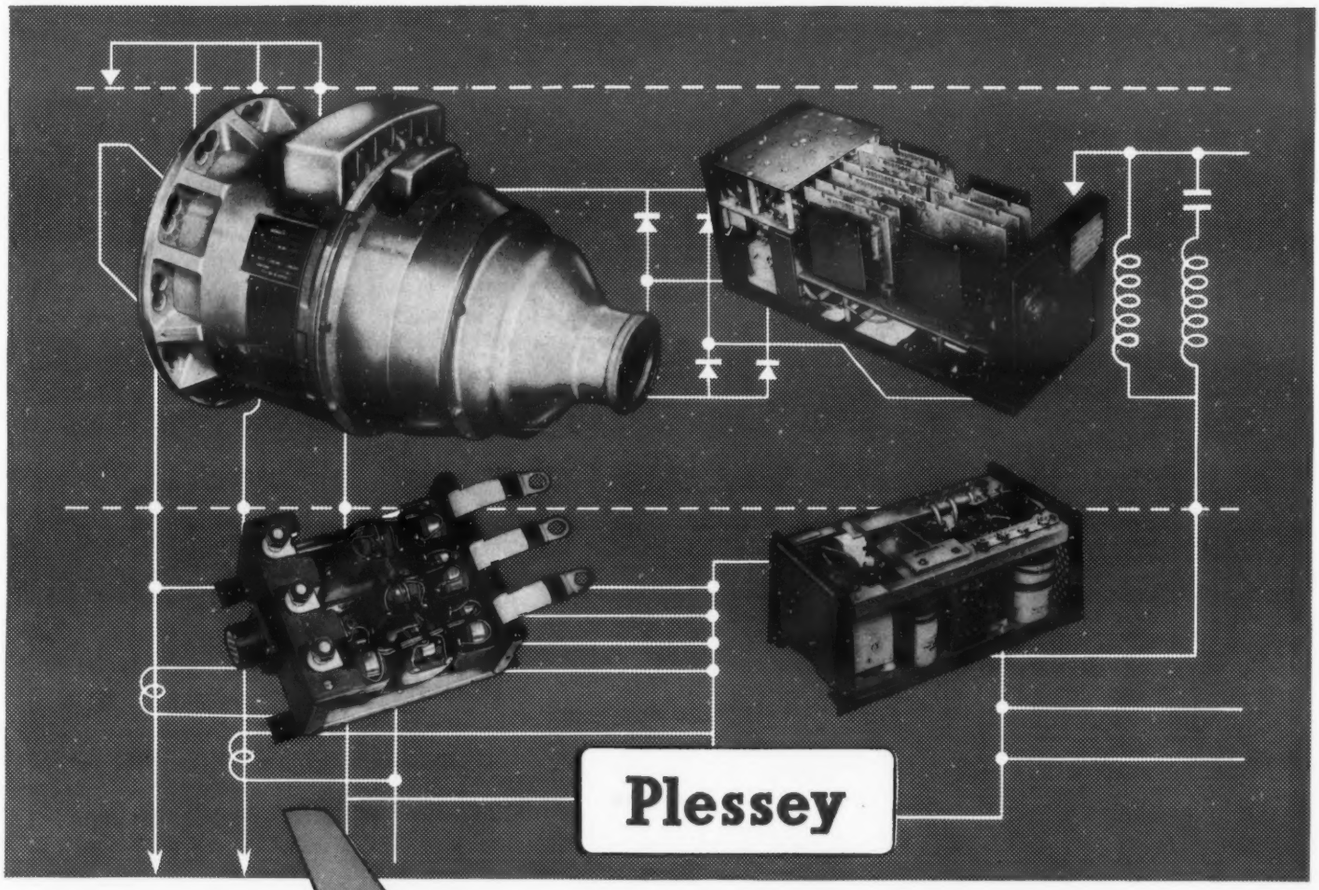

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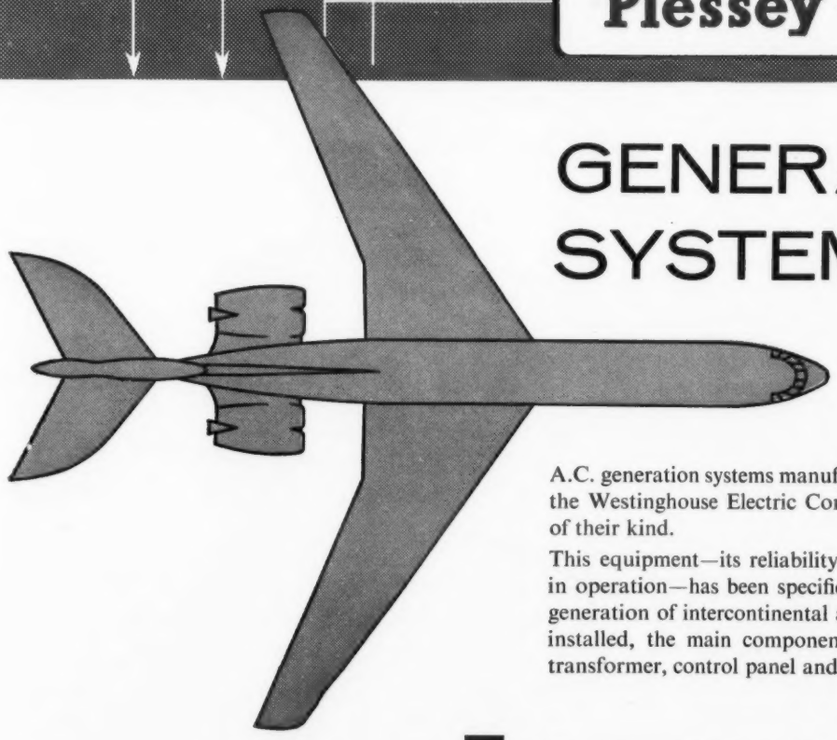

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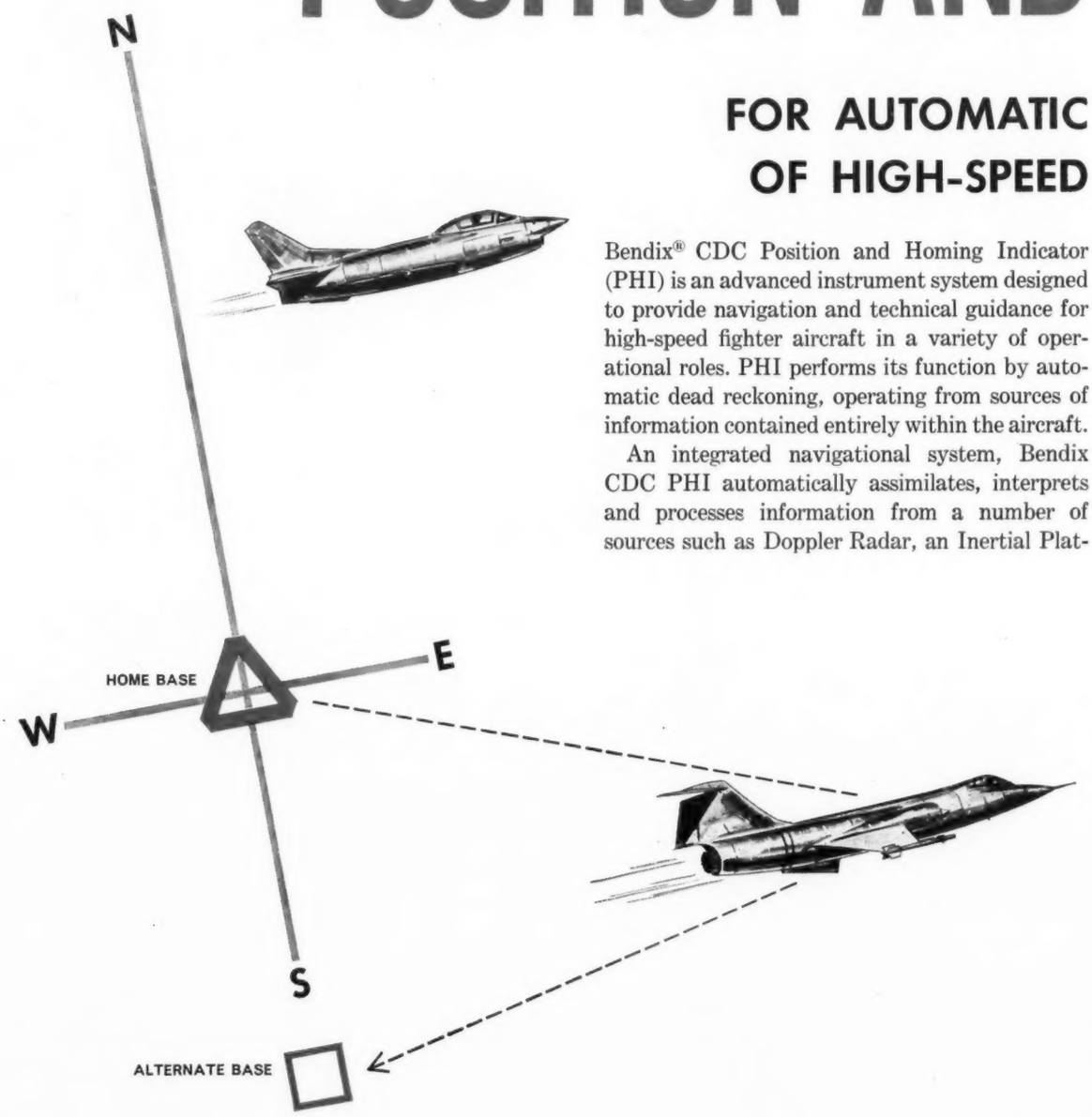

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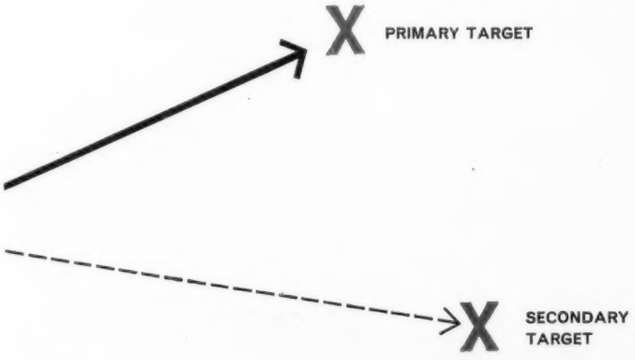

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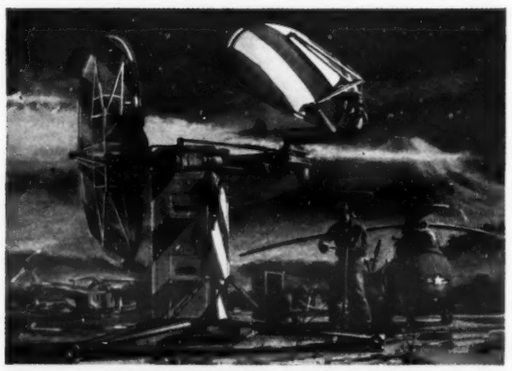


U.S. ARMY–AN/FPN-36 Quadradar

Gilfillan
LOS ANGELES

certain states meanwhile get their own national industries busy constructing varieties of VTOLs which SHAPE does not recommend. The surest means for securing adherence to NATO recommendations would be to have NATO purchase the aircraft it wants. Unfortunately, there is small chance of this taking place, because the spending mood of the traditional source of funds beyond the Atlantic seems to have momentarily stopped.

A second method has long been advocated by those circles who see NATO in its present shape as too much of a theoretical debating society for military sciences than anything else. They propose that the Western Powers should have a common military budget. This ideal is still far away, and the only installations which were financed in common include a number of antiquated airfields and several pipelines. What is more, Europeans and Americans want entirely different things from STOL and VTOL aircraft, as the leading article in this month's issue indicates. The solution desired by the U.S. Tactical Air Command—a 3,280 foot landing strip, a range of 3,500 n.m. and weight in the vicinity of 30 tons—is quite unsuitable for European operations.

The NATO programme

The basic requirement is for a tactical aircraft capable of operating on nuclear battlefields and penetrating behind them. Military staffs estimate the depth of the nuclear battlefield as being some 200 n.m.; this means that the aircraft required for penetration must be able to attack terrain, concentrations of reserves, factories and depots at distances of up to about 400 n.m. from its starting point, which will be inside the battlefield itself. The aircraft must also be suitable for carrying out photographic reconnaissance missions, for which it will be specially equipped in accordance with the weapons system formula. Finally, it must be able to defend itself if attacked while in the air. Although it will not be an interceptor, it must, if necessary, be capable of carrying armament enabling it to attack "aerial targets."

Although, as far as is known, the programme is limited to generalities, to leave designers free to choose between jet deflection or independent vertical thrust, the aircraft will be a true VTOL, in the sense that an aircraft which takes to the air in a hundred feet or so can be said to perform a true vertical take-off. The possibility of increasing the permissible take-off run is of great importance, for it determines the overload which the aircraft is capable of carrying.

"The aircraft must make do with the minimum ground organization." Such euphoric phrases are extremely dangerous, for behind them lurk a multitude of difficulties. Military thinkers have been forced to admit that a "limited logistic preparation" of the terrain is necessary. In actual fact, it will be extremely difficult, if not impossible, for a pure VTOL aircraft to take off from an unprepared terrain. Quite apart from the technical problem of recycling, the surface of the ground must be protected against jet efflux, and the aircraft must be protected against the stones or clods of earth which it raises from the ground. Special platforms must therefore be provided, and although these are far less expensive than airfields, they must exist before the arrival of the aircraft; this means that they will be spotted by the enemy if they are laid long before they are needed, and demolished on the commencement of hostilities, thus eliminating the element of surprise. The only solution to the problem is to have the platforms laid by a special transport force a few hours before the arrival of the tactical aircraft. Such a force would lay either grilles, after the manner of the last war, or specially designed plates of thick metal. There has even been talk of special plastics spread in liquid form by, say, helicopters; these materials would suffice for one landing and one take-off and would have to be renewed for each mission. One of the most important military requirements is however, the possibility of carrying out several sorties each day (probably of the order of four or five) during the few days which a land-air atomic battle will last.

The tactical assault mission consists of low-altitude operations at distances of some hundred nautical miles from "base" and at speeds slightly below that of sound (around Mach 0.95). But if the aircraft flies at medium altitudes, it must be able to perform longer penetration missions. And here we come to a point which is apparently one of the most controversial of all. Is it necessary for a tactical strike aircraft to be able to fly at supersonic speed? R. S. Hooper has discussed this problem so exhaustively in *Interavia* No. 5/1960 that it appears possible to agree with his conclusions.

Whether or not supersonic capability is required, and it is hard to know which nation demanded it (in any case, it is not Britain!), the aircraft must be capable of flying at Mach 2 at high altitudes, its ceiling being of the order of 50,000 feet.

The equipment will, of course, be highly comprehensive. The requirements for the navigation system are severe, perhaps excessively so, since they stipulate an accuracy of 1/1,000 of the distance, or 530 yd for 300 mi. But the aircraft must be able to carry out its approach in all weathers, only the final phase of the attack being made visually. It must therefore arrive in the immediate vicinity of the target even if it is at the extreme limits of the range. Moreover, the progress made in navigation holds out the hope that an inertial system will fulfil these requirements.

The aircraft will have a TACAN system and will, of course be equipped with the most up-to-date radio transmitters and receivers. Depending on mission, it will use either a reconnaissance system (automatic cameras) or a nuclear bomb such as the American Mark VII (or a more recent model). The bomb will be placed underneath the fuselage, and this poses a number of problems for a VTOL aircraft. How will it react to the flow of hot gases with which it risks being surrounded, in particular as regards the delicate launching and fusing mechanisms? Perhaps this consideration will swing the balance between the two large classes of VTOL aircraft, of which the SC.1 and the P.1127 are the principal European representatives.

As regards armament, the aircraft will probably be equipped with heavy cannon, an advanced fire control system (radar ranging at least) and air-to-air guided missiles. Finally, it must be light; its weight can be estimated at 10 tons, which represents a considerable increase over earlier estimates, which gave a weight of 6 to 9 tons.

Conclusion

While awaiting developments, military thinkers are fully aware of the fact that VTOL on its own cannot solve the problem of total mobility. In these pages, we have referred to the "transportable landing grounds" which were once the dream of the great Ader. Apart from these, consideration must be given to logistic facilities, which will provide VTOL aircraft of the future with the armament and fuel they need. According to R. S. Hooper (*Interavia* No. 5/1960), "Suppose there are three aircraft per site completing three sorties each per day [the programme will probably require more than this, and it would no doubt be more realistic to put the number at five] and consuming, say for a small aircraft, a modest two tons of fuel per sortie and disposing of one ton of armament each time. Thus $3 \times 3 \times 3 = 27$ tons per day per site [in reality $3 \times 3 \times 5 = 45$ tons]." And there are many other problems: spares, preparation of aircraft and armament, defence of the "base" against fifth columnists, etc.

Air Chief Marshal Sir Harry Broadhurst, Commander of Allied Air Forces, Central Europe, accompanied by Dr. E. J. Warlow-Daview, Chief Engineer (Aero) of the company, visits the test bed on which the BS. 53 was tested.

But we should be neither surprised nor discouraged too soon. The advent of a new weapon or a new and revolutionary procedure has always been attended by problems which have at first appeared insurmountable and which have finally been overcome without excessive difficulty, to enable the new discovery to develop with its undoubted advantages. We have only to think of the first motor cars to realize that VTOL is but the first step towards the total mobility of the aircraft, which is rapidly developing towards the flying saucer type of vehicle capable of moving in all directions and changing speed with a flexibility which will once again remodel the art of war. ⟷

V/STOL

Engine Considerations for VTOL Aircraft

By A. A. Lombard, Director of Engineering, Aero Engine Division, Rolls-Royce Ltd., Derby

Fig. 1: Dual Rolls-Royce RB.108 jet lift engines: specific weight 0.12 lb per lb of thrust; rapid response to throttle controls.

It is well known that a practical demonstration is necessary before one can obtain widespread interest and acceptance of any new principle. The recent demonstration of VTOL operation by the Short SC.1 research aircraft has been true to this pattern; it captured the imagination of a tremendous number of people to a much greater extent than any of the previous vast amount of engineering effort expended in this field by a limited number of enthusiasts.

The SC.1 incorporates a multi-engine powerplant system, generally termed a "composite" system, in which the lift and propulsion portions are in effect treated separately, permitting the selection of engines which are optimized for each of the main regimes of flight (jet-borne and wing-borne), i. e., to perform two quite distinct and separate duties. The Hawker P.1127, which has had its first tethered hover and is about to fly, is an example of a single-engined application, where lift and propulsion are performed by the same engine, giving the obvious advantage of simplicity.

The key to all forms of vertical or short take-off aircraft is the powerplant. As all such systems derive their lift during hover by accelerating a mass of air downwards, then they may be classified by their efflux velocity. At one end of the range is the helicopter with an efflux velocity of somewhat less than 100 feet per second and with an efficient hovering but low forward speed capability, at the other the direct jet lift aircraft having an efflux velocity of over 2,000 feet per second and inefficient hover but high flight speed capability. With a composite powerplant, efflux velocity for lift and propulsion engines may be different, so that high speed capability may be allied to low lift efflux velocity *(Figure 2)*. This gives flexibility of operation to the tactical aircraft; it is essential for the transport aircraft.

Lift engines

When one is searching for the greatest efficiency, it is axiomatic that one must make the minimum of compromise. In a system which exploits efficiency, there is no room for imposing loss of thrust or space, and increasing drag, weight and complexity, by turning or deflecting the gas during the whole of the cruise regime, when in fact deflection devices are required only during the jet lift phase.

The VTOL phase is clearly defined and capable of precise optimization once the transition speed is defined within reasonable limits, and a time allowance made for contingencies during final touchdown. The take-off technique has quite a small effect upon this optimization; one can therefore state the effect of engine design variables on the sum of the weights of lift engines, their installation and the fuel used during the lift phase.

The net result of such a study for a tactical strike application defines the simplest form of jet engine having the lowest possible specific weight compatible with a low cost per pound of thrust. The Rolls-Royce RB.108 shown in *Figures 1 and 3* represents the original engine designed and built to this concept. The lessons learned in the intervening seven years, together with new concepts of design and advances in materials, have permitted an outstanding improvement in specific weight and specific cost. Since such an engine is operated only at low altitudes and to low values of forward speed corresponding to transition to wing-borne flight, the normal range of operating conditions lies within narrow limits. This results in simplicity, compactness and low weight, together with simplifications of the combustion system, fuel supply, control system and lubrication system. Analysis of lift engine requirements for aircraft of more moderate performance could lead to fan lift engines, which are discussed later. Could there be a more exciting challenge to one's ingenuity?

Propulsive engine

The requirements of the propulsion engine in a composite system are perhaps more clearly defined than those for a conventional

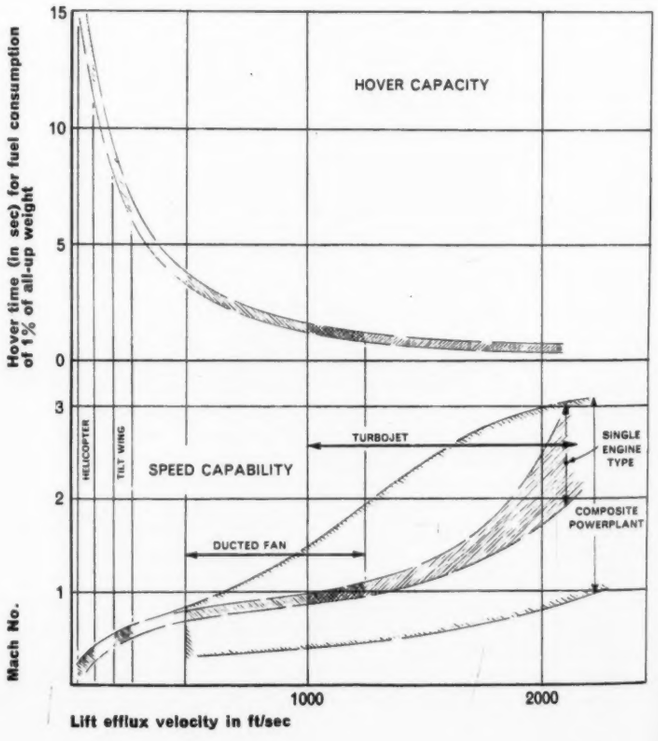


Fig. 2: Hover capacity *(top)* and speed capability *(bottom)* for various categories of VTOL aircraft, classified according to ascending efflux velocity. Values shown are hover time (sec) for a fuel consumption of 1% of the aircraft all-up weight, and attainable Mach number.

aircraft duty. There is no need to compromise the engine efficiency at typical cruising flight conditions by having to meet other requirements of conventional take-off. The size and type of propulsion engine can be defined by the normal flight cruise condition, with whatever margins are necessary to cater for manoeuvre without aircraft deceleration. For nearly all types of aircraft duty, the effect of the propulsive system upon aircraft weight and size is such that the engine must be of very high efficiency, i. e., an engine of high pressure ratio and of the by-pass type. It is fortunate that this particular fact has been recognized by all aircraft designers working in this field. For a low-level military operation of the "strike" type, the need for powerplant efficiency is paramount.

A typical engine of this class is the RB.163 shown in diagrammatic section in *Figure 4*. In *Figure 5* is shown specific fuel consumption plotted against the thrust required for level flight relative to aircraft take-off weight, for an assumed low-altitude mission. The RB.163 was optimized for high subsonic cruise. At the same time, it has sufficient thrust reserves for a typical tight turn. At economic aircraft cruise conditions there is substantially no deterioration in fuel consumption.

Comparison with single-engined aircraft

If we take an engine of the same high efficiency standard and scale it to produce both lift and propulsion for STOL operation (thrust to aircraft weight ratio 1.05), then at typical cruise conditions the engine will be heavily throttled and operating well up its consumption curve. Further throttling for economic aircraft cruise entails even more deterioration in fuel consumption, bringing the overall penalty to over 30 percent. In addition, the engine has been increased in size to a point where it is now required to give 140 percent more thrust per pound of aircraft weight than the propulsive element in the composite system and is therefore larger, heavier and more expensive. In the foregoing no penalties have been allowed for gas deflection during the cruising regime.

When the comparison is made between total powerplant weight plus fuel consumed for a typical low-level strike mission, the composite system shows to overwhelming technical advantage, as can be seen in *Figure 6*. Of course, in considering the large single engine, then the relatively high-efficiency engine as typified by the RB.163 may no longer represent the optimum, and a compromise involving some reduction in engine weight with a penalty in fuel consumption could lead to lower (engine plus fuel) weight than the 70 percent of aircraft take-off weight shown in *Figure 6*. However, it would still be substantially inferior to the composite powerplant by the very nature of the compromises made.

As so often happens, all the advantages do not rest with one particular system. It is recognized that the single-engine system, even allowing for deflecting nozzles, is somewhat the simpler to produce and, perhaps, maintain. So there we have it: the composite system as championed by Rolls-Royce with its high efficiency but somewhat increased complexity, compared with the single-engine system as proposed by Bristol Siddeley, with its greater simplicity. Each will have its application dependent upon detailed aircraft design requirements. The more ambitious the mission requirements, the more favourable becomes the composite powerplant.

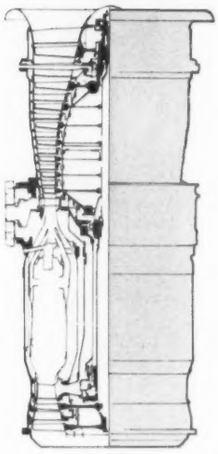


Fig. 3: Diagram of the Rolls-Royce RB.108 jet lift engine.

Where the aircraft combat performance is extremely high, the installed propulsive thrust may be sufficiently greater than aircraft weight to permit S/VTOL techniques by swivelling some or all of the propulsion engines.

Fan lift systems

Aircraft and engine companies have devoted considerable effort to devising some form of lift fan, which—because of its lower jet velocity—has a better fuel consumption and causes less ground erosion. A typical example of a lift fan is shown in *Figure 7*. This fan is the subject of a research programme sponsored by the Ministry of Aviation and is designed to meet requirements (including noise level) for commercial VTOL operation. The jet noise produced by its low efflux velocity is such as may be permissible for city-centre operation, but the high-frequency noise generated within the fan and turbine is quite unacceptable. This problem, together with jet erosion, is the main concern of this particular research programme. Factors affecting fan noise are now better understood, but its suppression without uneconomic penalty in weight and complication represents a very interesting research problem. The fan referred to was designed to be located within the aircraft planform and to be fed by air tapped from a common manifold supplied from auxiliary compressors driven by the main propulsive engines.

There is a variety of ways in which a fan may be utilized for lift. The lifting fans may be mechanically coupled either directly or through gearing, gas coupled, or remotely driven by compressed air either with or without preheating. Some typical systems are shown in *Figures 8 to 10*.

The choice of system depends upon aircraft performance, safety and noise requirements. Safety requirements will demand several fans, and the optimum number to provide the necessary balance moments at the lowest penalty in lift system weight, can readily be determined for a given aircraft geometry.

Clearly the problems with any form of lift are associated with their increased powerplant bulk (due to lower specific thrust inherent in the lower efflux velocity), greater weight and complexity. Because of the lower specific thrust, the momentum drag of the fan system at high transition speeds could be serious.

The probability of lower noise level and reduced erosion, and the advantage of lower fuel consumption during the lift phase, would appear to make the fan an attractive system for a minimum speed transport, either military or civil, where the problems of bulk and momentum drag would be less important. Such an aircraft should provide a practical solution to the inter-city "flying bus" operation and have operating economics between those of helicopters and conventional aircraft of comparable payload and range.

As with all direct lift systems, the effective thrust decay with increased ambient temperature demands that such engines shall be "flat" rated as far as possible. Also, a considerable amount of ingenuity, corresponding to that used in the design of the engine itself, should be exercised in the design of the powerplant installation, in order to keep the penalties to an absolute minimum in weight, cost and complexity. If there is sufficient ingenuity put into the installation design, then a total installation penalty of 50 percent of the engine weight should be capable of achievement.

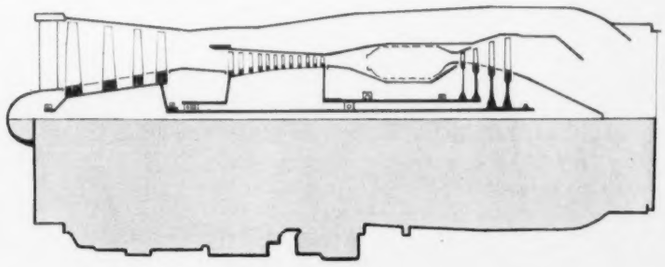


Fig. 4: Diagram of the Rolls-Royce RB.163 high-efficiency by-pass engine.

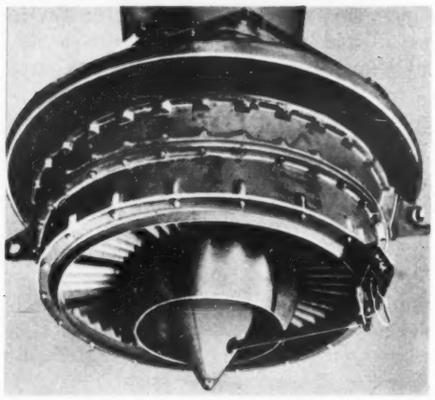
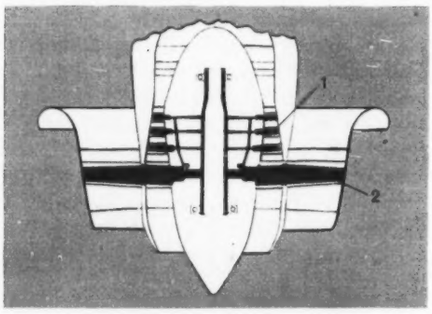


Fig. 7: Lift-producing fan with greatly reduced efflux velocity, consisting of a compressed air turbine (1) in the primary air flow and a concentric fan wheel (2) in the secondary flow.



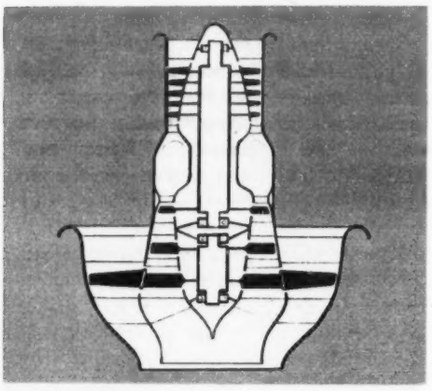
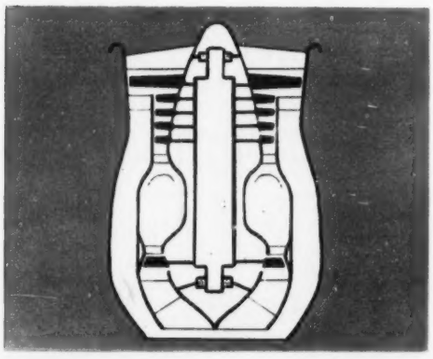


Fig. 9: Diagram of a lift fan gas-coupled to the basic engine: mean efflux velocity 1,000 to 1,250 ft/sec.

Fig. 8: Diagram of a lift fan mechanically coupled (possibly via a gear) with the basic engine: mean efflux velocity 1,000 to 1,250 ft/sec.



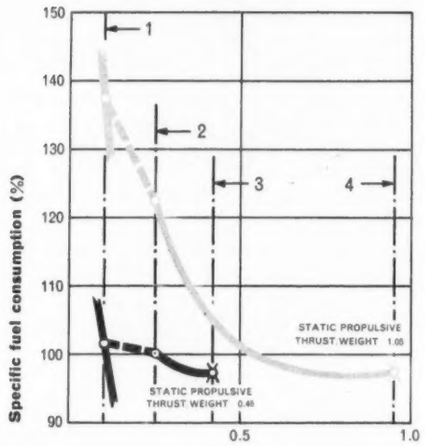


Fig 5: Specific fuel consumption for a pure propulsion engine in high-speed low-level flight (black curve) compared with fuel consumption for a scaled-up engine which also has to supply take-off power (grey curve). In the former case, the sea level thrust required is equal to 46% of the aircraft all-up weight, in the second 105%. Values compared are consumptions for economical cruise (1), high-speed cruise (2) and high-speed turns (3) and (4). In case 3, turns can be made at 5.5 g without loss of altitude.

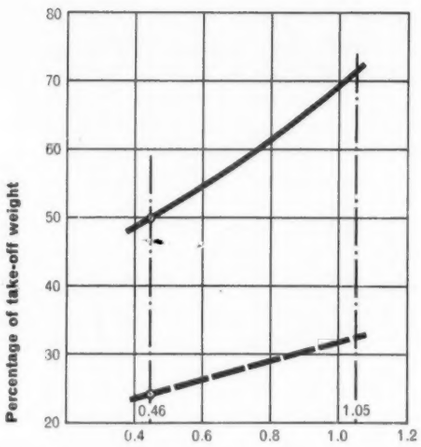


Fig. 6: Comparison between powerplant-plus-fuel weight (unbroken curve) and pure fuel consumption (broken curve) for the two solutions presented in Fig. 5, once again for a typical low-level mission.

Comparison with conventional aircraft

It has been said that if speed or range is a prime requirement, then the powerplant itself should not be compromised, nor should it be allowed to compromise aircraft aerodynamics. This demands a propulsion system optimized for cruise and a lift system optimized for the lift phase.

The time that has to be allowed for the lift phase has a great effect upon the optimum lift system. It is practicable to reach a reasonably high transition speed in about half a minute (with a similar time for landing), provided that the point of transition and the landing approach can both be determined accurately. It has been the practice to assume a total lift phase of three minutes; experience and the development of landing techniques will reduce this to two minutes or less. When this is achieved, the weight of the lift powerplant plus the weight of the fuel consumed during the lift phase can be kept down to around 15 percent of the aircraft all-up weight. It should be borne in mind that the conventional runway-based aircraft would have consumed some fuel in getting to the same point in space as the transition point of a VTOL aircraft.

If a similar amount of weight can be saved by reducing the weight of the propulsive powerplant and of aircraft structure weight and fuel reserves, and by dispensing with the devices required for conventional runway take-off and landing (undercarriage, high lift flaps, thrust reversers, etc.), then VTOL can be achieved without penalty in cruise performance.

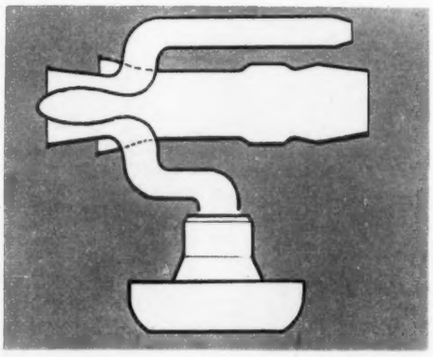
Prospects

It is my belief that further work on the yet undeveloped VTOL aircraft will yield an increasing rate of return and that in the not-too-distant future the VTOL aircraft will be superior both in performance and flexibility of operation to the runway-based aircraft.

The present situation in regard to VTOL can be likened to the early days of the jet aircraft of around 1942. The difficulties are about as great, involving the same revolution in aircraft design and powerplants. The potential future for VTOL is equally great and certainly presents the greatest challenge in the field of aircraft design since the advent of the jet aircraft. It is my personal conviction that all new aircraft designs commencing five years from now, or all major aircraft in operation in 1975, will incorporate some form of VTOL system.

I look forward to the day when one can take off from any desired point, rise gently, quietly and smoothly, accelerating with merely a feeling of exhilaration to a flight speed consistent with the stage length to be covered, and finally gently decelerate to a low contact speed at destination, regardless of the weather conditions. Surely this is the ultimate goal in transportation at which we are all aiming? ⟷

Fig. 10: Diagram of a lift fan remotely driven by compressed air: mean efflux velocity 500 to 1,000 ft/sec.



V/STOL

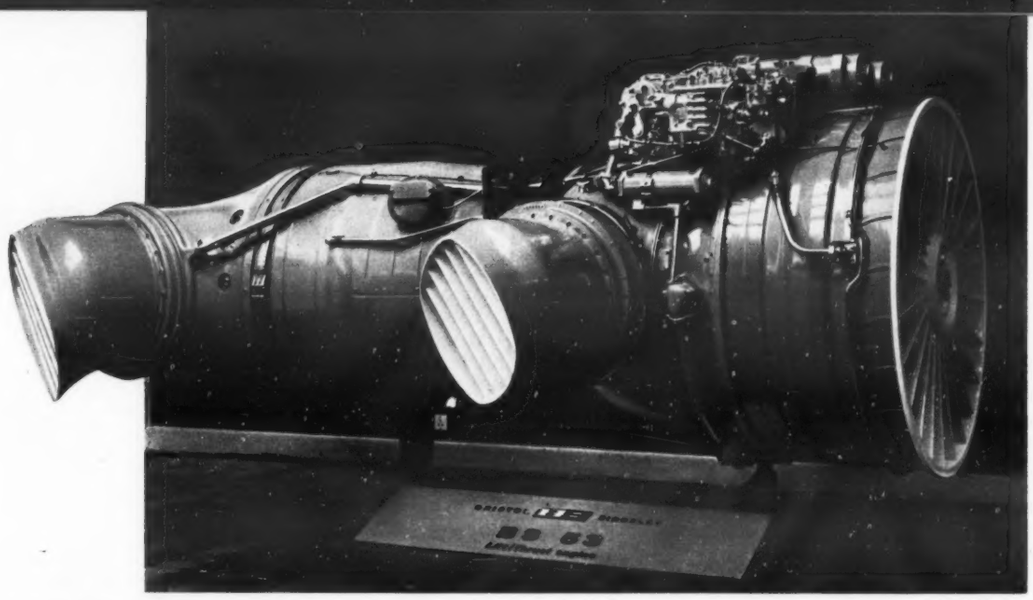


Fig. 1: Bristol Siddeley BS.53 with a thrust vector setting of 45 degrees.

Fan Engines for Vertical and Short Take-Off Aircraft

By Dr. S.G. Hooker, CBE, Technical Director, Aero, Bristol Siddeley Engines Ltd., Bristol

The problem of obtaining vertical take-off on an aircraft can be specified as:

- Generating a vertical thrust greater than the weight of the aircraft;
- Ensuring that this thrust acts at the centre of gravity of the aircraft;
- Arranging to rotate the thrust from the vertical for take-off through a range of angular positions during the transition from jet-lift to wing-borne flight and, finally, into the horizontal for normal flight;
- Providing adequate stability for the aircraft during the transition period from zero forward speed to full aerodynamic control in normal flight.

It is evident that there must be some penalty for vertical take-off, but modern military requirements demand that this shall not be at the expense of speed or manoeuvrability, and that the penalty should be taken on range and kept as small as possible.

These conditions automatically imply that the powerplants must be jet engines, and lift by helicopter rotor, by tilt wings, or propeller must be relegated to very special missions and requirements.

Proceeding, therefore, on the basis of jet-propelled aircraft only, we find that these fall into two main categories:

a) The single-seater strike or interceptor aircraft, which is normally powered by a single engine;

b) The large multi-seater, multi-engine type aircraft suitable for long-range transport operations.

First, consider the single-seater strike aircraft. It will evidently be an advantage if this aircraft can be lifted and propelled by one engine, and it is for this duty that the Bristol Siddeley BS.53 engine has been designed.

The engine consists of a two-spool ducted fan, whose general arrangement is shown in *figures 1 and 2.* The fan is a two-stage compressor and supercharges the independent high-pressure compressor of the engine. Surplus fan air is discharged from two ducts, one on either side of the front of the engine, and the final exhaust jet is also bifurcated into two ducts. All four ducts terminate in nozzles which can be rotated into any angular position from the vertical to the horizontal, and in this way the thrust can be vectored in a very simple manner into any angular direction, as essentially demanded by vertical or short take-off aircraft.

An engine of this type has many practical advantages:

1. It can be mounted horizontally in the fuselage of a single-seater aircraft in a conventional manner such that its vertical thrust coincides with the centre of gravity of the aircraft.
2. The jets can, if required, be directed rearwards and the aircraft used for conventional take-off and landings.
3. The engine can be started and tested, and the machine taxied, with the jets directed horizontally rearwards. There is, therefore, no problem of ground erosion and debris entering the engine during these phases.
4. For short take-offs (say 200 yards) the aircraft can be accelerated with the jets directed rearwards, and then the nozzles can rapidly be deflected downward, to say 60°, when 87% of the thrust will be given in lift, and 50% of the thrust of the engine will still be available for horizontal acceleration. In such cases, the aircraft will clearly sweep its debris behind it well away from its own intakes.
5. Even for vertical take-off the engine can first be opened up to power, and then the nozzles rapidly deflected vertically to give the minimum time for jet erosion and debris to be thrown around.
6. Combining as it does both lift and thrust in one engine, the BS.53 keeps the maintenance and logistic problems due to dispersal to a minimum.

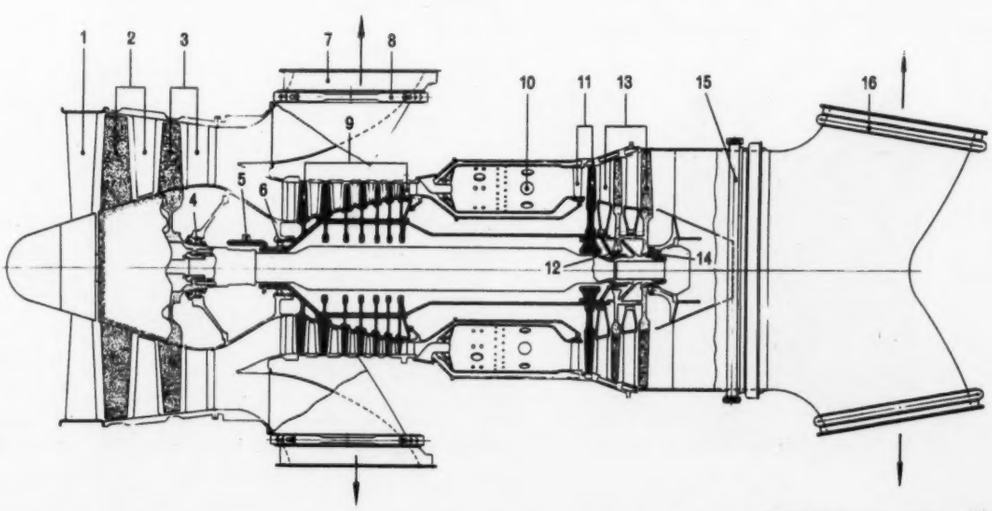


Fig. 2: Plan section of the BS.53

1 – Inlet guide vanes
2 – First stage of low-pressure fan
3 – Second stage of low-pressure fan
4 – Front bearing of inner main shaft
5 – Auxiliary gearbox drive
6 – Front bearing of outer main shaft
7 – Connecting flange of the rotating nozzle for thrust vector control of the cold airflow
8 – Rotating nozzle bearing ring
9 – Seven-stage high-pressure compressor
10 – Cannular combustion chamber with flame tubes
11 – High-pressure turbine stage
12 – Rear bearing of outer main shaft
13 – Low-pressure turbine stages
14 – Rear bearing of inner main shaft
15 – Connecting flange of jet-pipe system for hot airflow
16 – Bearing ring for rotating nozzle for hot airflow.

7. Being a ducted fan, the BS.53 has lower jet velocities and temperatures than the simple jet lift engines, and as a consequence the problem of ground erosion is reduced.

Evidently, one of the most important criteria of a lift engine is its thrust-to-weight ratio. Current jet engines such as the *Avon, Viper, Olympus,* and *Conway* now in service in Great Britain have a thrust/weight ratio of about 4:1. In 1956 the Bristol Siddeley *Orpheus* achieved a thrust/weight ratio of over 6:1 and is now in service at this figure. By virtue of the high static thrust of the ducted fan, the BS.53 achieves a thrust/weight ratio of 7:1, while at the same time retaining the well-known advantage of the ducted fan engine in giving low specific fuel consumption, both at take-off and under cruising conditions.

The advantage of the ducted fan in cruising fuel consumption is shown in *figure 3.* With a by-pass ratio of 2:1, a gain of approximately 10% can be achieved over the best that can be done with a jet engine of corresponding compression ratio. The curve shows also that the best fuel consumption is obtained at a lower specific thrust than with the jet engine. This indicates that the engine can be throttled to a low proportion of its take-off power while still maintaining its best fuel consumption. This property is very desirable in an engine which serves for both lift and propulsion. To lift the aircraft the engine must give a thrust greater than the weight of the aircraft, while for propulsion purposes at sea level only one-quarter or one-fifth of this thrust will be required. Consequently, it is vital that the engine should be capable of throttling at low altitudes to low percentage powers without too great an increase in specific fuel consumption. On the other hand, the great power of the BS.53 is always available for climb, acceleration and manoeuvrability in turns, which would certainly not be the case if the lift were obtained by separate lifting engines. At high altitudes, the large engine is again an advantage, and its full cruising power can always be utilized with benefit to the range and performance of the aircraft.

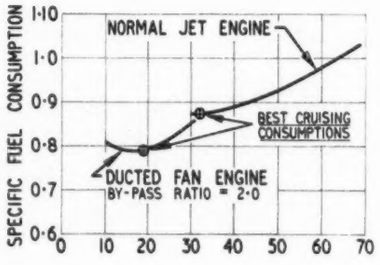
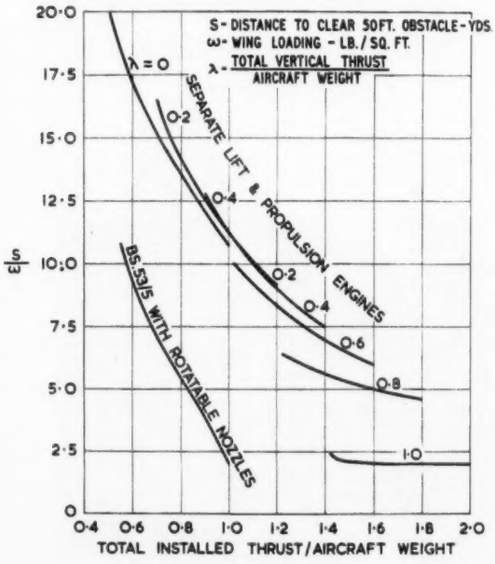


Fig. 3: Specific fuel consumptions for a normal jet engine and a ducted fan engine with a by-pass ratio of 2; both curves are for cruise at 500 knots true airspeed and 36,000 ft. The consumptions are indicated as a function of specific thrust; the compressor temperature rise is 350 °C.

Fig. 4: Comparison of STOL take-off performances of aircraft with one type of powerplant (BS.53/5 with rotating nozzles) and with a composite powerplant (separate engines for lift and thrust). The graph is based on ISA sea level conditions and takes account of the total installed thrust-to-weight ratio, the vertical installed thrust in relation to take-off weight, and finally wing loading. The ordinate gives the take-off distance in yards to clear a 50 ft screen, relative to wing loading in lb/sq. ft.



In this latter case, the propulsion engine does not contribute to the lift, or the lifting engines to the propulsion. In *figure 4* the comparison is shown of the take-off performance of the two systems. In this diagram the vertical ordinate is the take-off distance in yards divided by the wing loading in lb/sq.ft., and the horizontal ordinate is the total installed thrust in the aircraft, i.e., the sum of the horizontal thrust and the vertical thrust. The curves on the upper right of the diagram are drawn of the aircraft, and show that as this ratio approaches 1.0 so the take-off distance is clearly independent of the horizontal thrust.

With a total installed thrust of 1.4 times the weight of the aircraft divided such that the vertical thrust is equal to the weight of the aircraft, the take-off distance will be seen to be 250 yards, if the wing loading has a typical figure of 100 lb/sq.ft. Even if the total installed thrust is increased to twice the weight of the aircraft by increasing the horizontal thrust to be equal to the weight of the aircraft, the take-off distance is hardly diminished. The reason is that the horizontal thrust never contributes to the lift and merely serves to push the aircraft over greater take-off distance during the time that it is becoming airborne.

The lower curve drawn for the BS.53 with rotatable nozzles shows that the take-off distance for an aircraft fitted with this type of engine is very much shorter than with the combination

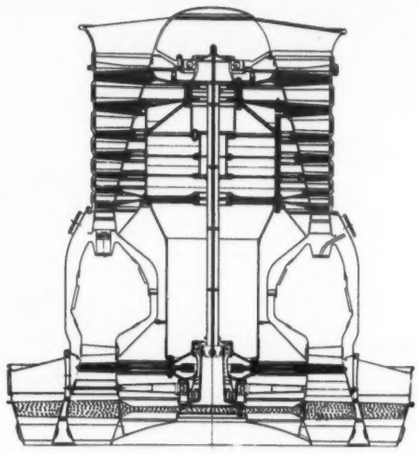


Fig. 5: Section of a by-pass lift engine with aft fan, developed by Bristol Siddeley. With a by-pass ratio of 8:1, an average efflux velocity of approx. 600 ft/sec could be achieved; thrust-to-weight ratio 0.0715 lb/lb or 14:1.

engines, the reason being that the direction of the thrust can be varied during the take-off run always to point in the optimum direction. Thus the procedure for take-off would be to point the nozzles horizontally and use the full thrust of the engine for acceleration up to a pre-determined flying speed and then to rotate the nozzles to say 60° or 70° downwards, in which case more than 80% of the thrust of the engine could be available for vertical lift and 50% for horizontal thrust. At this point, the total installed thrust is 1.3, and the saving in take-off distance by this procedure is quite remarkable, giving a take-off distance of 250 yards (with 100 lb/sq.ft. for wing loading) for an installed thrust of unity.

*

Turning now to the multi-engined transport, the arguments are, of necessity, somewhat different. Firstly, it is now imperative to ensure the safety of the aircraft in the event of an engine failure during the vertical take-off or transition phase. The only practical way of doing this is to fit a large number of engines (say 8 or 10), so that in the event of one failing only 10 to 12% of the total thrust is lost. To regain this it is only necessary to open up the remaining engines. In this case, therefore, it appears necessary to develop special lifting engines which operate only during take-off and landing, and are shut down during the cruising flight of the aircraft.

Since the problem is to obtain a jet lift equal to the weight of the aircraft, it would clearly be an advantage if the propulsion engine could also give lift during take-off, and here again the BS.53 is attractive as the main propulsion power plant capable of augmenting the lift at take-off by rotating its nozzles.

A specialized simple fan lift engine can be developed, giving 14 lb of lift for every pound of engine weight. Similar, and probably slightly better, figures could be obtained from specialized jet engines.

The fan lift engines might well be of the form shown in *figure 5,* which illustrates an aft fan of the type developed by the General Electric Company in the United States. A high by-pass ratio, possibly reaching 8:1, is desirable in order to get the maximum static thrust and the minimum fuel consumption. At the same time, the low jet velocity (approximately 600 ft/sec at 8:1 by-pass ratio) will reduce the problem of noise and jet erosion.

The main disadvantage of the lift fan is that it is bulkier than the simple jet lifting engine, but whichever is chosen it seems clear that the propulsion engine must be of the BS.53 type, embodying the efficient ducted fan for propulsion, and yet capable, by simple rotation of the nozzles, of contributing all of its thrust for vertical take-off.

Stabilization of VTO Aircraft

By H. G. Conway, Director and Chief Engineer, Short Brothers & Harland Ltd., Belfast

The new and fundamental problem which the design of vertical take-off aircraft presents to the aircraft engineer relates to stabilization. The part of the problem dealing with hovering stability is not too difficult, as has already been demonstrated by the SC.1 and other experimental aircraft of the "Flying Bedstead" type. But the problem of achieving adequate stability and control during transition from hovering to forward flight, that is from synthetic to aerodynamic stability, is a major one and one where there is limited experience.*

There are obviously two ways of tackling a new problem such as this; one is to put the minimum of special equipment into the aircraft in order to get it flying in the shortest possible development time, leaving operation problems to be faced later; the other is to go more slowly and to develop in parallel with the aircraft what is considered to be a fully operational system capable of going into service. Most of the VTO research aircraft that have been built so far, particularly those in the USA, have followed the first course. Short's policy has, since 1954, been to follow the second course. During the development of the SC.1, the loss of two Flying Bedsteads for reasons which are directly or indirectly associated with control problems perhaps underlines the correctness of the approach. The fact that several other VTO aircraft have also been lost may further strengthen this viewpoint, although the precise reasons for the accidents are not known in all cases.

It may be of interest to compare the basic differences between a VTO stabilization system and a conventional autopilot on a normal fighter aircraft.

The first difference (and it is a major one) relates to the authority or power level of the control system. A conventional autopilot produces forces on the aerodynamic control surfaces at such a rate that, in the event of a runaway, the pilot has two or three seconds in which to regain control by switching off the autopilot. By comparison, the VTO aircraft of the SC.1 type has an authority at least five times greater, and a catastrophic runaway could occur in less than half a second. The design criterion of the SC.1, and indeed of several other comparable aircraft, is that the control system should be able to impart an angular acceleration in pitch or in roll of about one radian per second. This means that the aircraft can achieve about 30 degrees of attitude change in the first second with a "theoretically perfect" runaway.

The basic problem is thus to ensure that under no conceivable circumstance can a single failure cause such a runaway, and indeed it is highly desirable that even two faults occurring at the same time do not cause a dangerous manoeuvre. Since 1954 Shorts have therefore been working on a fully triplicated system, so arranged that no possible failure of one channel of the system (except a mechanical break of the coupled output shaft) will cause difficulty.

In more recent years similar work has been initiated in the application of triplicated systems to the new autopilots designed for use with automatic landing systems for normal aircraft, since even an ordinary autopilot cannot be allowed to run away at an altitude of less than about 300 feet during a final approach. Triplex systems are thus here to stay; indeed we may predict that in future quadruplicated systems will become common.

As a direct result of the high authority of the system, the SC.1 has made use of hydraulic servos rather than an electro-mechanical type. Instantaneous output rates of several hundred degrees per second are required, and although these are theoretically possible with electric servos, the degree of mechanical complexity would be very high, and it would be extremely difficult to achieve the necessary level of integrity on account of the number of gear trains, clutches, etc.

The use of hydraulic servos in the autopilot field is unusual, although the necessary techniques have been developed for guided missiles. In the development of the SC.1, Shorts made use of a servo which had been originated at the RAE and used by the firm on the GPV guided missile. This was re-designed and adapted for the triple SC.1 installation.

The principle of an electro-magnetic torque motor, operating directly a single stage valve, has been retained throughout and, although the original torque motor as designed by the RAE has been superseded by an improved one produced by the firm, we have never contemplated making any basic change, such as to use a two-stage valve of the type popular on missiles in the USA. The reasons for this are clear enough—the small precision electro-hydraulic valve is perhaps the weakest link in the whole chain, and it is far better to keep it simple and robust, and then to signal its satisfactory performance, than to introduce extra stages which would considerably complicate the fault detection system and increase the chances of blockage by dirt or other failure.

A major effort in the SC.1 was concentrated on the development of one of the smallest items on the aircraft—a miniature pick-off sufficiently sensitive to signal valve position. The difficulty here is that the valve motion under normal hovering is extremely small (perhaps 10 or 20 microns); the transient errors in position during response to an external disturbance may momentarily be of the same order (or even greater). Thus

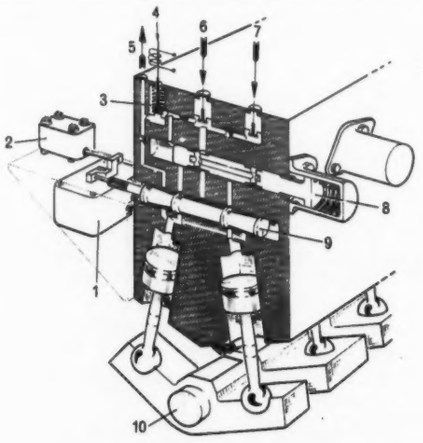
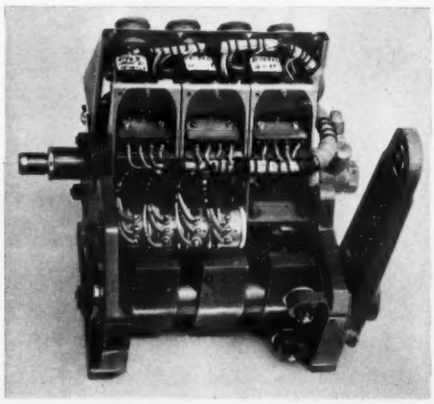
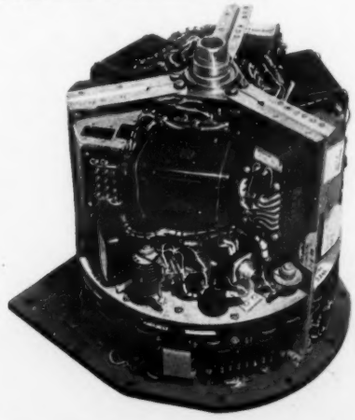


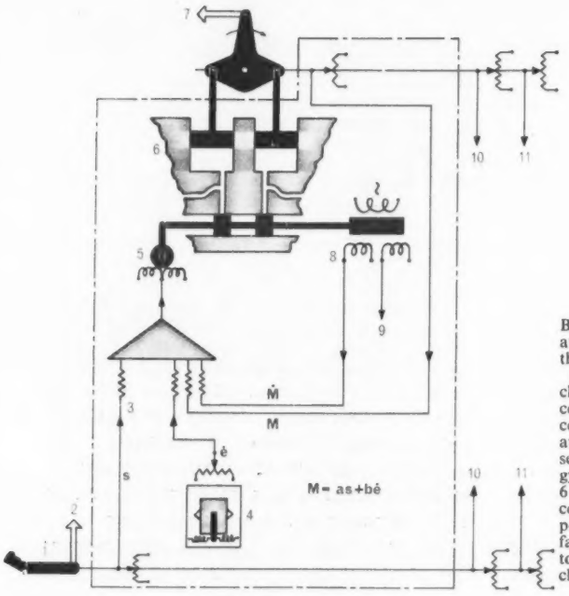
Diagram (top) and view (bottom) of the servo motor assembly. 1 – electromagnetic torque motor; 2 – a. c. pick-off; 3 – pilot-operated by-pass valve; 4 – electro-magnetic solenoid; 5 – tank; 6 – pressure; 7 – emergency pressure; 8 – by-pass valve; 9 – control valve; 10 – output shaft.



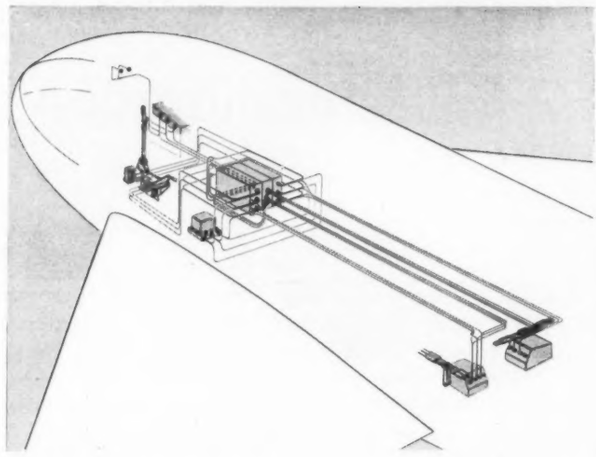
Triple gyro control unit and amplifier.



* See report on the Short SC.1 in *Interavia* No. 11/1960, page 982 et seq.



Block diagram of a roll autostabilizer channel for the Short SC.1. The other two parallel-connected channels are identical. 1 – control column; 2 – to control surfaces and from autopilot when fitted; 3 – servo amplifier; 4 – rate gyro; 5 – torque motor; 6 – servo motor; 7 – to control nozzles; 8 – valve position pick-off; 9 – to fault detection circuit; 10 – to channel 2; 11 – to channel 3.



Layout of autostabilization equipment in an aircraft. All units are provided in triplicate and are connected in parallel independently of each other.

the problem is to develop a fault detection system which indicates that the three valves are moving correctly and yet can ignore normal transient errors. Almost every system which could be thought of by a team of intelligent young engineers has been tested, and the final system which is now flying, making use of automatic test signal injection, is considered the optimum.

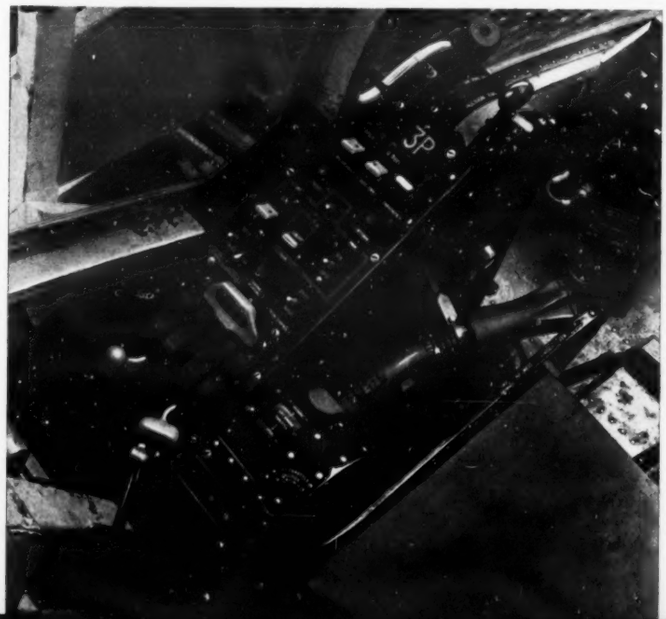
If the mechanical design of the SC.1 equipment is such as to ensure a high degree of reliability, it is the electric circuitry which gives the equipment the required characteristics and makes it appear satisfactory from the point of view of the pilot—a matter, naturally enough, of some importance. As is well known, the SC.1 makes use of a mixture of attitude and rate terms, although the bulk of the flying so far carried out has been made with rate terms predominating. So far flight operations have been confined to conditions of good visibility, and the pilot has found that the rate damping introduced in pitch and roll greatly facilitates flying. As was clearly seen at the Farnborough demonstration, the aircraft appears to be, and indeed is, under the perfect control of the pilot. Height control on the other hand is achieved at present by direct coupling of the pilot's left-hand lift throttle lever to the lift engines, and the good response achieved is undoubtedly attributable, at least in good measure, to the good throttle response characteristics of the small Rolls-Royce RB.108 engines. There is some doubt whether the same could be said of a large single lifting engine. Those who watched carefully the aircraft doing a transition at Farnborough may have noticed the precision of vertical control and how, when the propulsion engine throttle was opened and the lifting engines tilted backwards, the pilot was able to correct without any difficulty the slight loss of lift which occurred when he started transition.

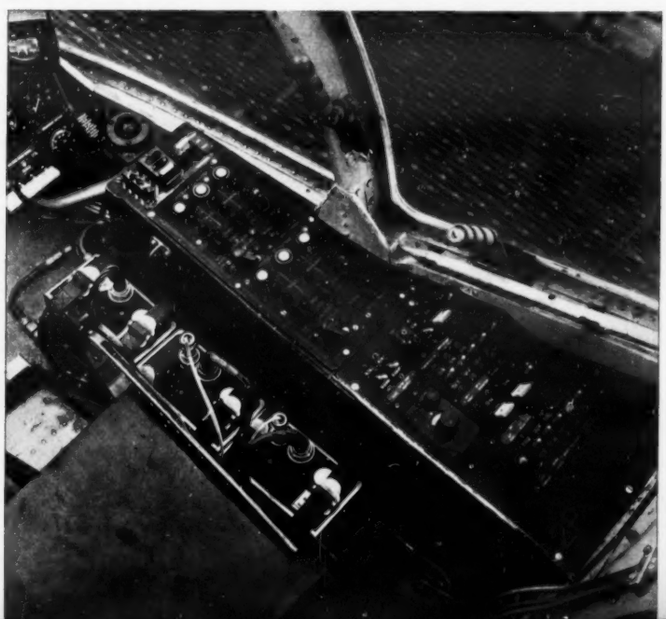
More advanced equipment is however currently being developed, not only for auto-stabilization, but also for approach control; the objectives here are to facilitate or make possible full blind landing, since the firm believes that the full potentialities of VTO will not be exploited until all-weather operation is possible. The new equipment introduces a more positive vertical reference to the auto-stabilizer and in some cases to the aircraft, so that a given attitude can be held during an automatic approach. There is a provision for coupling in automatic signals from the ground in order to initiate transitions, that is to start decelerating by engine tilting, so that the aircraft arrives automatically over a selected point prior to final let-down. Coupled to this is an automatic throttle system which will receive signals from accelerometers mounted in the aircraft and will automatically vary lifting engine power as aerodynamic lift decreases and aircraft speed reduces. New flight instruments are needed for this phase of flight, in order to monitor the process; attempts are being made to keep these as simple as possible and indeed to integrate them into existing displays where this is possible, in the interests of the already over-worked pilot.

Vertical take-off aircraft are fascinatingly interesting. Although we at Shorts have quite naturally taken pride in our work and had been most stimulated by seeing the SC.1 in operation, we had not expected others to be quite as enthusiastic as, for example, they were at the SBAC Show. The SC.1 performed faultlessly on the seven days of the Show, and on each day the final landing was accompanied by spontaneous applause from the hard-bitten audience: something which has probably never happened before at Farnborough.

We do not feel we have an exaggerated opinion of our own merit! Our efforts to exploit the jet lift principle meet the inevitable difficulties which "cut us down to size." But surely jet lift VTO has a bright international future! ⟷

Details of the SC.1 cockpit. Left, engine controls: If the lever next to the pilot's seat is lifted, the thrust of the lift engines is increased; the thrust of the propulsive engine can be varied either by the twist grip on the lift engine lever or by the lever on the top of the console. Right, the autostabilizer controls, which are separate for each channel.





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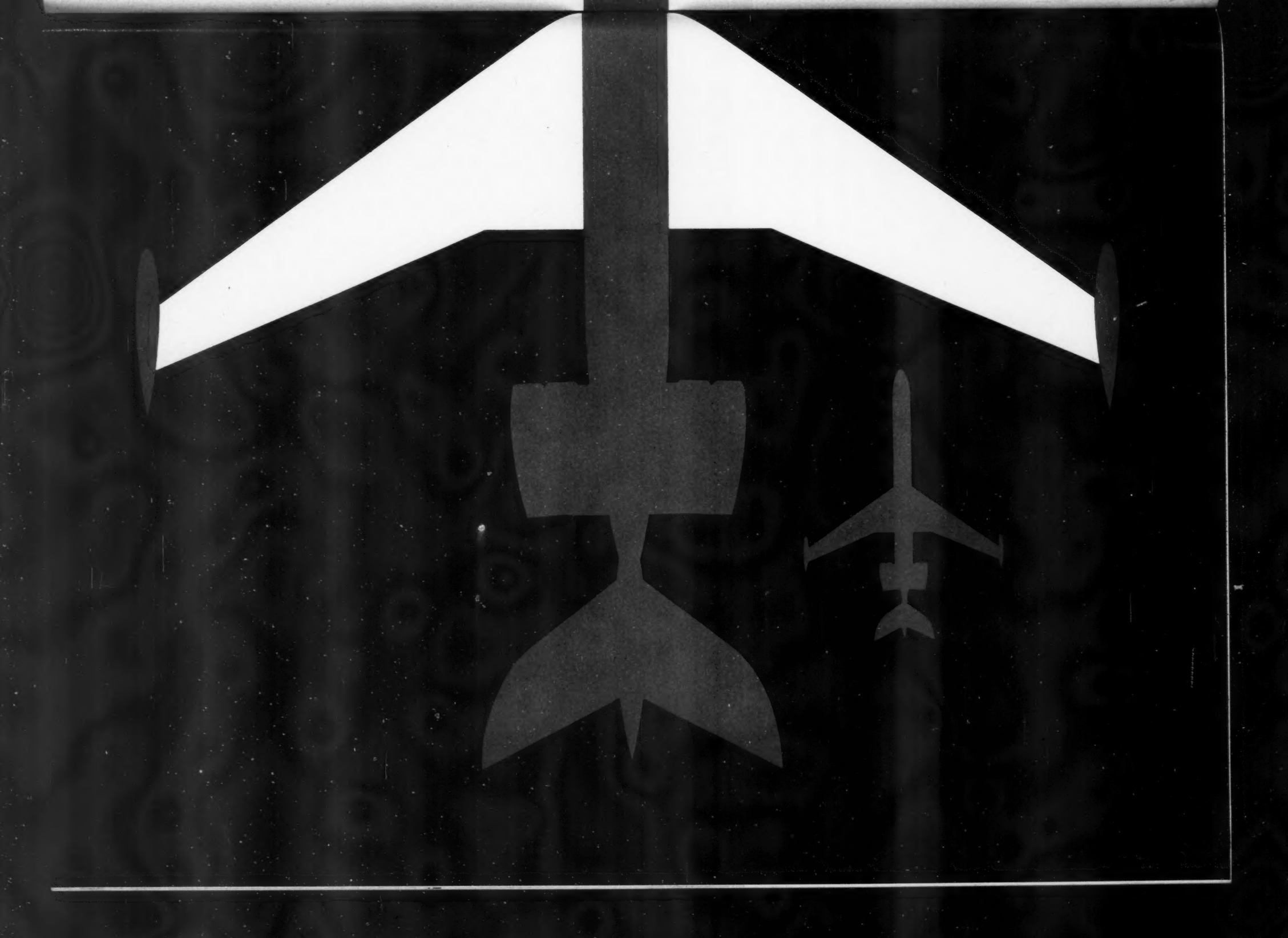

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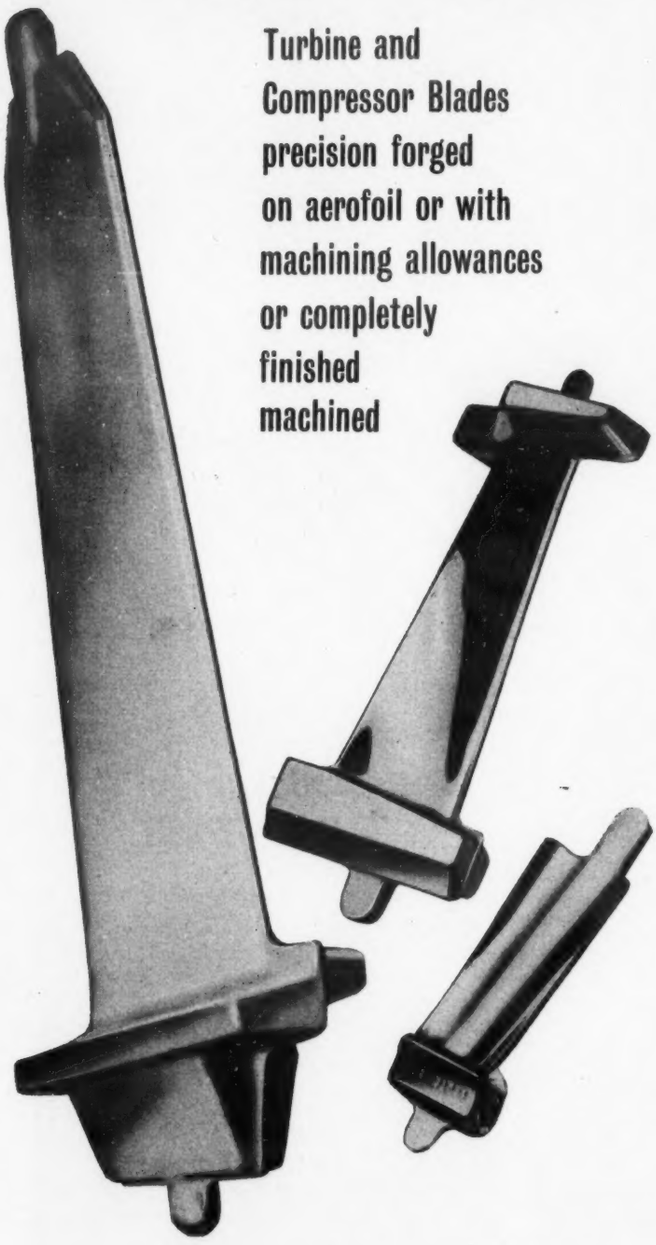

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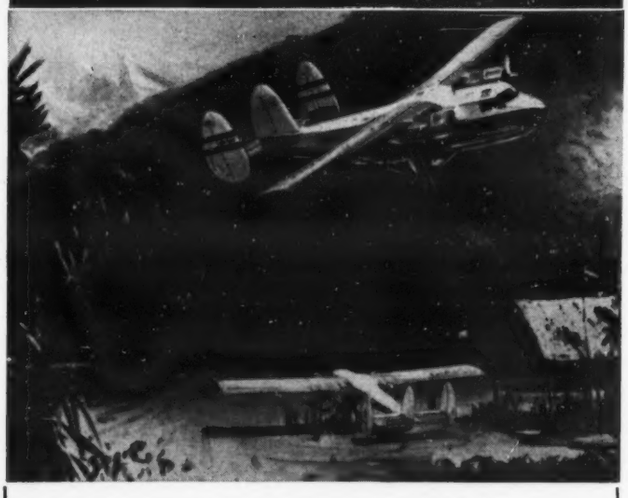

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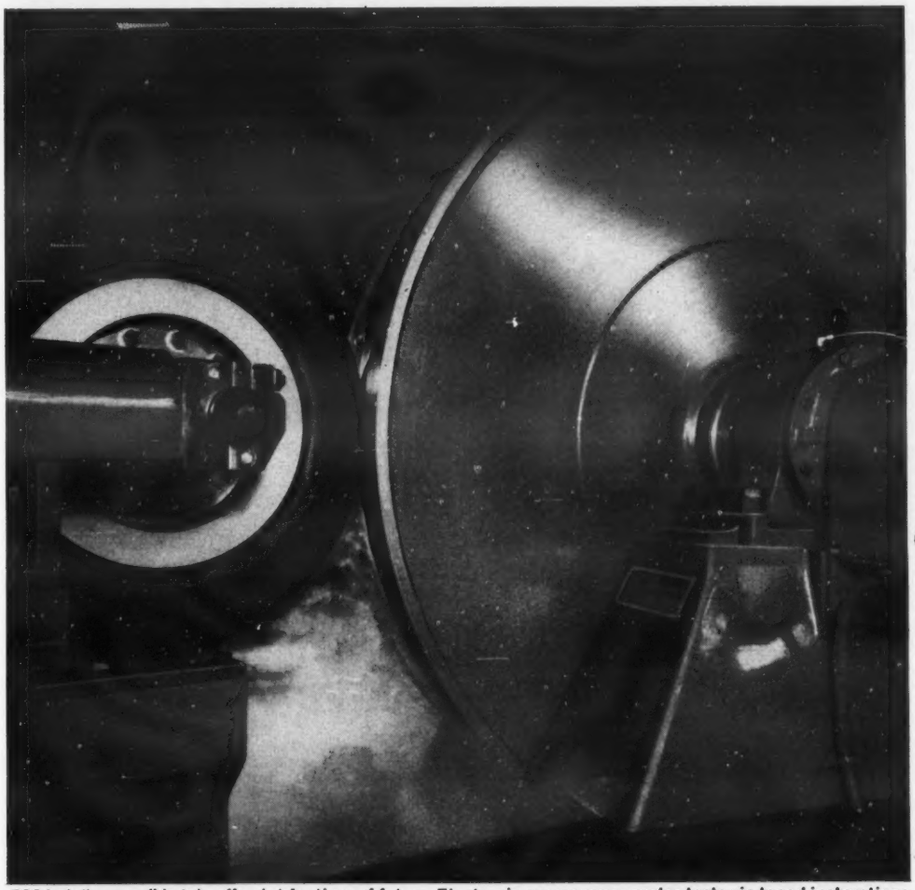

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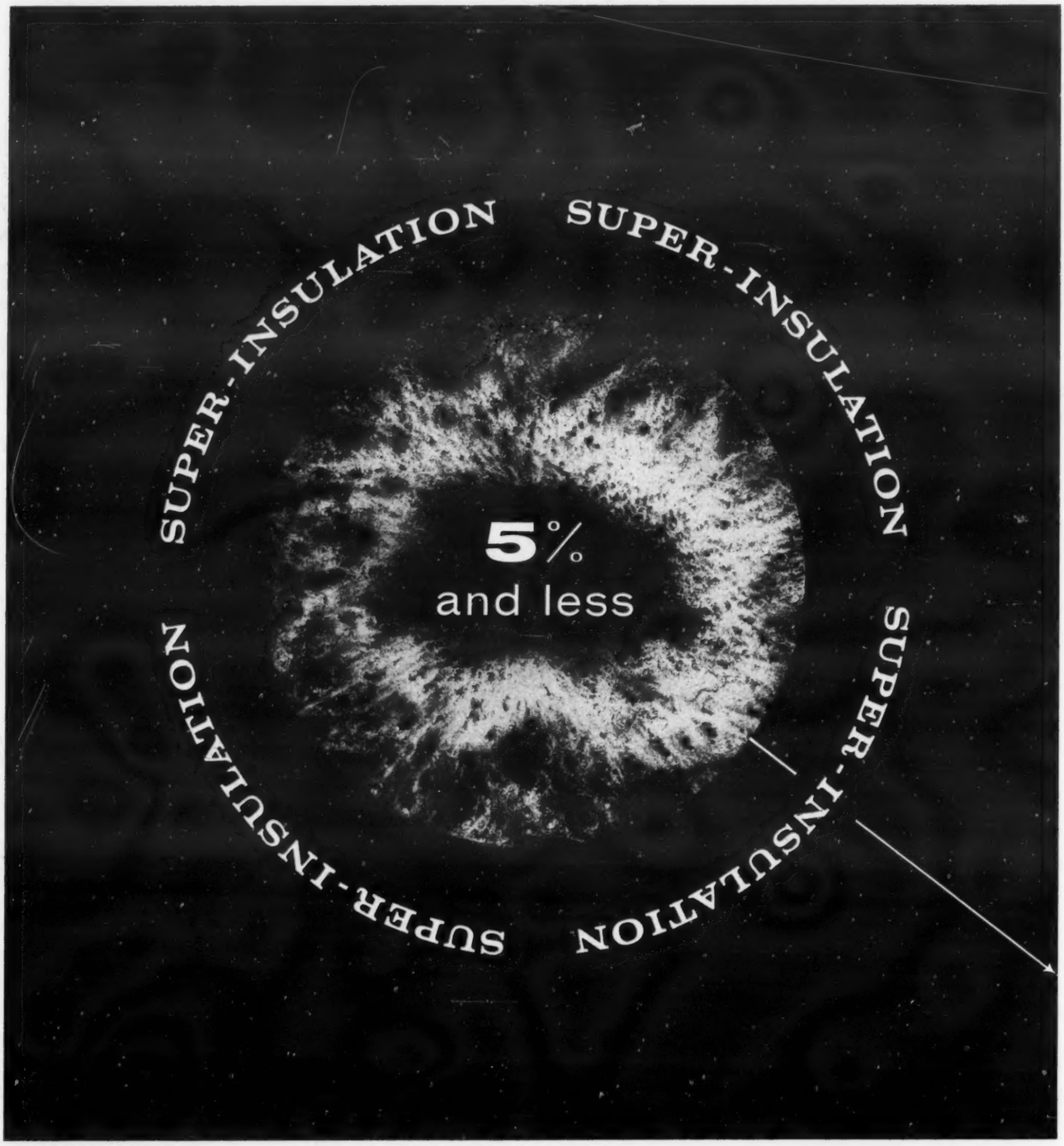

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A Problem of the Moment :

Short or Vertical Take-Off and Landing ?

by Professor Giuseppe Gabrielli,
Manager, Fiat Divisione Aviazione

The editors of Interavia *are particularly gratified that Professor G. Gabrielli has consented to write an introduction to the following series of articles on short and vertical take-off aircraft. For Fiat had ample opportunity, during the NATO lightweight strike fighter competition, to carefully weigh the pros and cons of all designs in this aircraft category. Designers the world over are now faced with the task of finding a more modern replacement for the Fiat G.91, developed under the supervision of Gabrielli.* Editors.

The theme of the present issue of *Interavia*, namely the *raison d'être*, the design and the practical applications of short or vertical take-off aircraft, is dealt with by eminent specialists, but before the discussion it might be useful to give a clear definition of what is meant by the abbreviation S/VTOL, or short and vertical take-off and landing.

In the writer's opinion, VTOL means "take-off and landing perpendicularly to the ground," independently of the methods and formulae used to achieve this; this applies equally to propeller-driven and jet aircraft, whatever the system of lift used in normal flight, whether it be aerodynamic, jet lift or a combination of the two.

The essence of VTOL being thus defined, it is clear that STOL lies between VTOL and normal take-off and landing. But the definition of STOL is not as simple as all that, for it must of necessity be based on the determination of the maximum distance required for take-off and landing, a distance which is traditionally measured from the base of an obstruction whose regulation height lies between 35 and 50 ft. This distance must clearly be established in accordance with a criterion such as a particular condition of operation; it must also, however, be as long as possible for technical reasons. Too short a take-off distance or too high an obstruction would require solutions which would be in no way different from the more costly and complicated ones demanded by VTOL.

When jet lift systems are available at virtually the same price, weight and specific fuel consumption as aerodynamic lift systems (wings), VTOL will be the natural outcome of technical progress. But, with things as they are at present, this equality between jet lift and aerodynamic lift is still a long way off, even in the case of fighters and supersonic bombers. Aircraft will still have wings for normal flight, so that their powerplants will be used mainly to provide propulsion; the aircraft will, however, have lift devices for take-off and landing. The wing will remain the primary lifting agent, and it will therefore be convenient to use it for take-off and landing as well. But for this purpose the aircraft take-off distance will have to be as short as possible, though not too short to enable the wing to act as a lift device; this implies a fairly high take-off speed.

Jet engines specially designed for lift will be characterized by an extremely high thrust-to-weight ratio (of the order of 16 to 18 : 1); they can therefore be used as auxiliary powerplants and as lift devices by the use of jet deflection.

For the reasons given above, it appears that *the requirement for the STOL aircraft to clear a 50 ft screen in 500 ft raises considerable problems, equal to those of the VTOL aircraft* (as regards weight, cost and the difficulties of maintenance and pilotage).

If operational necessities require this condition, it will be preferable to resort to pure VTOL, with a strictly vertical take-off. In the writer's view, to speak of STOL is reasonable only in the sense in which its limits are kept fairly wide, say 1,000 ft to clear a 50 ft screen.

Naturally enough, this conception is open to criticism from many points of view, and it will undoubtedly be greeted with some reserve. Nonetheless, all those who will be called upon to use STOL aircraft ought to consider very seriously the fact that STOL techniques should benefit in some way from the speed which is imparted to the aircraft on take-off by its ground roll. The suggested distance of 1,000 ft to clear a 50 ft screen enables the aircraft, with the high specific thrusts obtainable today, to exploit to the full the advantages of lift generated by flow around an airfoil, using for take-off that simple and economic device, the wing, in all its forms.

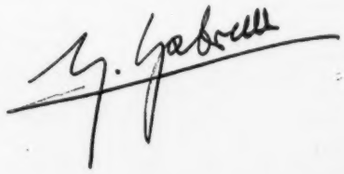
To impose too narrow restrictions on STOL means that designers cannot benefit from the substantial advantages offered by advanced high-lift devices (blown flaps, etc.), which are the result of decades of research aimed not only at reducing drag and increasing lift, but also finding the most reliable and economical means of producing a lift force. Whatever the shape it takes, VTOL does not draw on these devices for take-off and landing; technically, this increases the difficulty of the problem from the point of view of price and convenience of operation.

It is precisely for these reasons that the writer feels that the construction of a VTOL aircraft *capable of practical operation* will require at least another ten years, during which large sums must be devoted to research, and to the construction and testing of a large number of experimental prototypes; among these are the Short SC.1 and the Hawker P.1127, the harbingers of a future which will certainly be brilliant.

For the same reasons the writer considers that, along with the important landmarks in the field of VTOL research, to which a number of firms (Bell, Breguet, Bristol, Convair, Curtiss-Wright, Dassault, Doak, Fairey, Fiat, Fokker, Hawker, Hiller, Lockheed, Nord-Aviation, Rolls-Royce, Ryan, Short, Sud-Aviation, Vertol and others) are applying their talents with considerable tenacity, comparable research and design work should be undertaken in the STOL domain.

Here Fiat is directing its efforts towards research into the means by which, in the present state of the art, the STOL solution can be exploited to the full to achieve an aircraft suitable for practical operation. This research will be continued with the greatest determination; some concrete results have already been obtained with our G.95 project.

Some Fiat engineers will now state the basic essentials of the solution which they propose, the purpose of their article being to define the scope of what can be achieved here and now with STOL. ◂◂



European and American V/STOL Combat Aircraft

By Interavia Study Group

Previous articles have discussed some of the basic problems in choosing engines and stabilizing VTOL aircraft; the following articles attempt to give a comparative survey of airframe projects which have so far been made public. *Interavia* No. 7/1960 (p. 789) contained an appraisal of the state of development in Europe and America in the summer and gave an idea of the great variety of designs existing at that time. In particular, there was a clear difference between the NATO formula for a successor to the Fiat G.91 single-seat combat aircraft and the specifications of the USAF Tactical Air Command as set forth in SOR (Specific Operational Requirement) 183. Although NATO members and the representatives of industry delegated to the corresponding NATO committees are not yet fully agreed as to the appearance which a multi-purpose combat aircraft will take, it is certain that—unlike the aircraft specified by the USAF—it must take off and land vertically.

The basic principles of the NATO formula were laid down months ago in Washington by the Standing Group of the Atlantic Powers, and it is highly probable that the European allies will finally agree on a supersonic aircraft with all-weather fire control system and navigation equipment. The requirements for VTOL characteristics have been kept fairly flexible, vertical take-off being demanded only with reduced take-off weight, while a runway length of 200 to 300 yd for take-off at maximum weight is considered acceptable. The designs submitted by Fiat do not initially make provision for VTOL characteristics and therefore seem to be more in line with the American concept.

Hawker Siddeley, in Great Britain, is studying designs for both main powerplant concepts, namely for the Bristol Siddeley BS.53 lift/thrust engine and Bristol Siddeley and Rolls-Royce separate lift and thrust engines. Fiat proposes an interim solution with the G.95/1 and G.95/2, which are developments of the proven NATO lightweight strike figther; these proposals are completely independent of the two engine concepts mentioned. The Fiat projects will be dealt with in detail in the following series of articles, together with further proposals from other well-known manufacturers.

The U.S. firm of Lockheed has been making some interesting studies with a view to fitting the F-104 single-seat multi-purpose combat aircraft with additional lift jets in wing-tip pods, while keeping the existing airframe and propulsive powerplant. Both the Lockheed project and the VTOL version of the *Mirage III* proposed by Dassault use already proven airframes and equipment, so that both could be available in a shorter time than aircraft which have to be designed from scratch.

*

Apart from Lockheed and Republic, no U.S. aircraft manufacturers are interested in the NATO competition for a VTOL successor to the G.91. On the other hand, several large concerns are concentrating on the development of a STOL combat aircraft for Tactical Air Command under SDR (System Development Requirement) 17. This specification is based on SOR 183, which demands a combat aircraft weighing over 20 tons, with a ferry range of 3,500 n.m. With a speed of Mach 2.4 at high altitude and a maximum speed of over Mach 1 at sea level, such an aircraft could perform several tasks on a single mission (e.g. all-weather reconnaissance and strike) and could take off with reduced all-up weight with a run of only a few hundred yards. With normal all-up weight, the aircraft's range would be about 1,500 n.m., and take-off distance for normal missions would be between 5,000 and 6,000 ft. As already reported in earlier editions, the firms of Boeing, Convair, Douglas, Lockheed, McDonnell, North American, Northrop and Republic are taking part in this competition.

Boeing has been working for almost three years on a twin-jet, two-seat supersonic strike aircraft of the type now demanded under SOR 183. Powered by two Pratt & Whitney engines (probably TF-30s, each delivering 15,000 lb thrust), the aircraft would be supersonic over its entire altitude range. The wing could be swept rearwards for fast flight, giving it a delta form with a span of only 33 ft. For take-off, landing and subsonic flight, the wing would be extended so that it would have a span of 67 ft, considerably improving the lift/drag ratio and enabling the aircraft to take off and land in very short distances. The variable-sweep wing principle, investigated by NASA and put to the practical test by Bell many years ago, is also used in the design submitted by Republic.

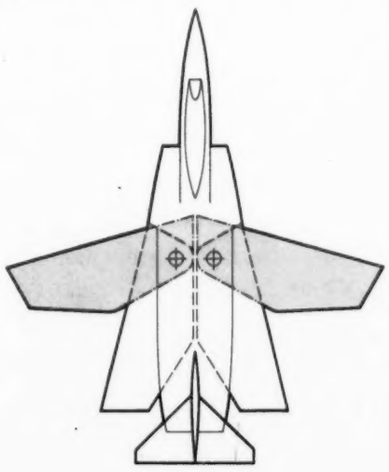
As recently reported from Washington, the choice of a prime contractor for the STOL aircraft is likely to be delayed for some time. The Aeronautical Systems Center of Air Materiel Command had announced that a decision would be taken by the end of 1960, but Government circles now seem to feel that the feasibility of the V/STOL concept should be re-examined before a multi-million dollar contract is awarded. The progress achieved in Europe with VTOL aircraft, and the fact that most air bases in the European and Asiatic theatre of war lie open to destruction, have no doubt been among the reasons for this reappraisal.

The following is a brief survey of the projects under development in Europe

Development firm and type designation		*Power-plant*	*Engine type*
France			
Breguet	—	○→ ↓	1 Bristol Siddeley B.S.53 (approx. 17,500 lb thrust)
Dassault	VTO *Mirage III*	○→ ↓	1 developed Pratt & Whitney JFT-10 (17,530 lb thrust with reheat) plus 6 SNECMA lift engines, each with 5,500 lb thrust or 8 SNECMA lift engines, each with 4,400 lb thrust
Dassault	*Balzac*	○→ ○ ↓	1 Bristol *Orpheus* plus 8 Rolls-Royce RB.108
Nord-Aviation	—	○→ ↓	1 Bristol Siddeley BS.53 (approx. 17,500 lb thrust)
Sud-Aviation	—	○→ ○ ↓	1 Pratt & Whitney JFT-10 plus 6 Rolls-Royce lift jets
Great Britain			
Hawker Siddeley	P.1127	○→ ↓	1 BS.53 (approx. 15,000 lb thrust)
Hawker Siddeley	—	○→ ○ ↓	1 jet engine for thrust plus several separate lift jets
Short	SC.1	○→ ○ ↓	1 Rolls-Royce RB. 108 plus 4 RB.108 (2,010 lb thrust each)
Short	PD.49	○→ ○ ↓	1 Rolls-Royce engine for thrust plus several Rolls-Royce lift jets
German Federal Republic			
Northern Group (Weser Flugzeugbau and Hamburger Flugzeugbau)	—	○→ ↓	1 Pratt & Whitney JFT-4D or TF-33
Entwicklungsring Süd (Bölkow-Heinkel-Messerschmitt)	—	○→ ↓	Several deflectable suspended Rolls-Royce RB.153 lift/thrust jets

○→ thrust engine; ○ ↓ lift engine; ○→ ↓ combined thrust and lift engine.

Drawing of a two-seat, twin-jet STOL combat aircraft with variable-sweep wings. The area shaded in grey shows the wings opened to full span; they can be swept backwards to achieve a delta planform. Boeing Airplane Company is working on an aircraft project with this configuration.



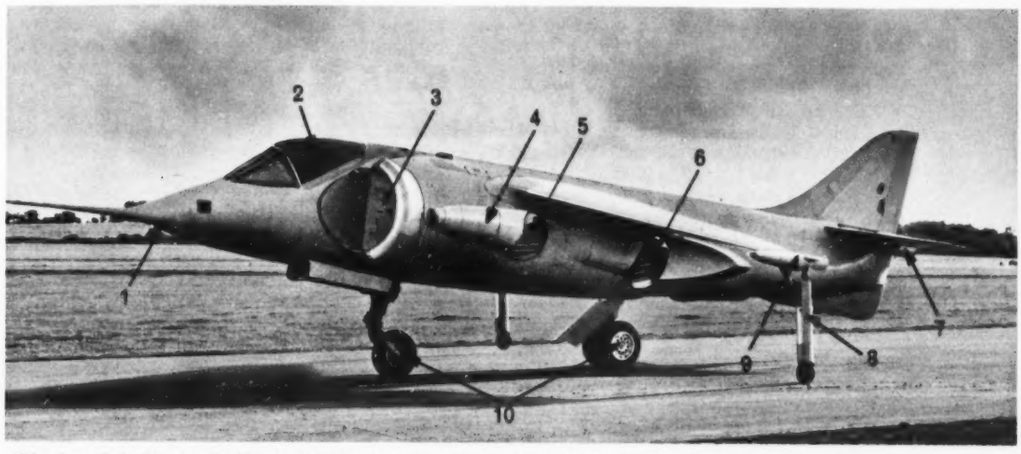
The Hawker P.1127

Unlike the various test vehicles that have flown to date, the Hawker P.1127 is the first VTOL military machine which has been designed from the outset for operational employment. The hovering trials of the aircraft have been completed in less than five weeks from the time that the prototype made its first vertical take-off. On several occasions the aircraft has been untethered and has hovered free of any ground restraint. With the hovering trials completed, the next major phase of flight testing will cover its flight performance and handling as a conventional aircraft. The last and most important stage will be the critical phase of transition from hovering to forward flight.

Several prototypes of the P.1127 have been ordered by the Ministry of Aviation, and discussions are now going on in the Air Ministry as to whether batch production should be ordered. There is an immediate RAF requirement for the P.1127 (which is designed purely for subsonic speeds) in roughly its present form, for use in ground attack and tactical reconnaissance roles, and also in a two-seater trainer version. In addition, the RAF is anxious to develop operational experience with VTO as soon as possible.

The situation has, however, been somewhat confused by the knowledge that NATO will require a VTOL *supersonic* strike aircraft capable of Mach 2 plus at altitude. For large-scale production, both the RAF and NATO have to make a compromise between speed of delivery and an aircraft in being, and supersonic projects which will take some years to develop. Hawker Siddeley has found it more reasonable to put a subsonic machine into service as early as possible, to fulfil the pressing military requirement and to obtain the necessary experience, while proceeding with the development of the supersonic VTO aircraft which can be phased into service later.

It has been reported that the P.1127 weighs almost 15,000 lb, which would indicate a thrust for the present BS.53 engine of slightly above this figure. There is no doubt, however, that later versions of the BS.53, by the continual process of development, would be capable of twice this thrust. These developed versions would allow for the construction of fairly large supersonic aircraft capable of carrying a heavy warload. It is known that Hawker Aircraft has been working on supersonic developments of the P.1127 for some time past, but the future of these will rest on the RAF and NATO decisions.



Side view of the Hawker P.1127. 1. front jet control nozzle for pitch stabilization; 2. transport canopy, with good visibility forwards and downwards; 3. engine intakes with boundary layer foil and thick, variable geometry intake lips; 4. fairing for the front rotating engine nozzle (with opening for cooling at front end); 5. port front rotating jet nozzle (cold air); 6. port rear rotating jet nozzle (hot air); 7. rear jet control nozzle for pitch stabilization; 8. outrigger undercarriage; 9. port jet control nozzle for roll stabilization; 10. tandem main undercarriage.

One of the illustrations accompanying this article shows design details of the P.1127. The entire fuselage centre section is taken up by the BS.53 fan engine, whose air intakes — at both sides of the fuselage — appear to be adjustable in the first prototype, evidently to provide the engine with adequate airflow during static runs and hovering flight. Both the twin-wheel main undercarriage and the nosewheel retract into the fuselage, the former rearwards, the latter forwards, and there are supporting wheels at the wingtips which retract into cylindrical fairings. In the nose and fuselage rear (directly behind the elevator unit) are jet nozzles for pitch stabilization which, with the two wing-tip nozzles for roll stabilization, are fed by pressurized air from the compressor. The fuel tanks are presumably between the engine intakes in front of the BS.53 and in the fuselage behind the engine. External loads can be carried under the fuselage between the two wheel bays and on underwing pylons.

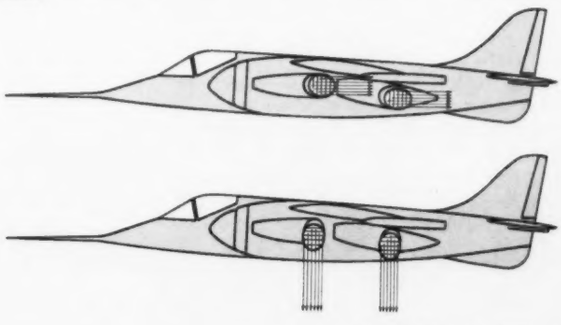
The P.1127, which will be comparable in performance with the Hawker *Hunter*, is intended to have a maximum speed of between Mach 0.93 and 0.95 in level flight, and speeds of over Mach 1 in dive. Wing span is 24 ft 4 in., length 41 ft 2 in. and height 10 ft 3 in. All-up weight for vertical take-off should not exceed 15,000 lb, though it could be raised to as much as 17,500 lb for oblique take-off; even with the latter, the P.1127 would still weigh less than the last *Hunter* series.

As already mentioned, the RAF is also interested in a two-seat version of the P.1127, which would differ from the initial version in having a lengthened fuselage nose to accommodate the second ejection seat. A problem which still remains unsolved is the removal of the engine for repair and maintenance. At present the BS.53 can be taken out of the fuselage only from above (after removal of the rotating nozzles). Easy accessibility of the engine would be an important factor for operation from temporary landing grounds.

As these lines go to print, the second prototype is nearing completion, and further flight tests of this revolutionary VTOL aircraft will doubtless be awaited with much interest. ◆◆

Bristol Siddeley BS.53 fan engine with four rotating nozzles. With a thrust-to-weight ratio of approximately 7 : 1 the BS.53 has a specific fuel consumption of the order of 0.6 lb/lb/h.

Diagram showing gas jet deflection through the rotating engine nozzles. Above, cruising with rearward facing nozzles; below, hovering with downward facing nozzles.

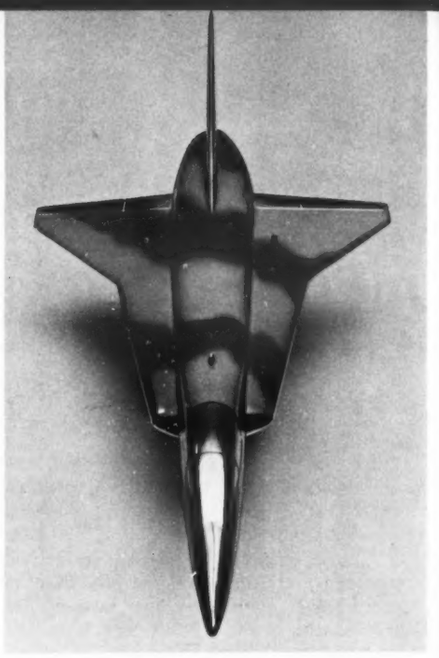


The Short SC.1 and the Short PD.49

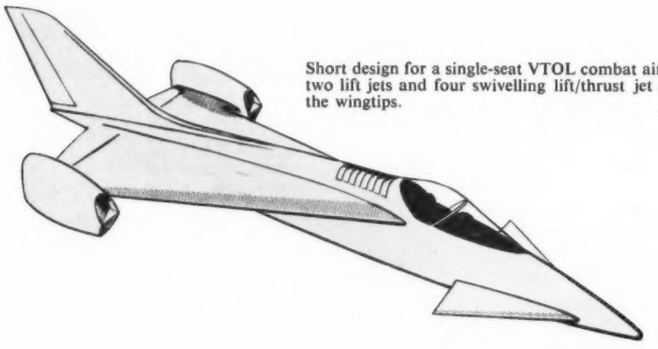
Interavia has repeatedly paid tribute to the pioneering work done by Shorts in the vertical take-off field (see *Interavia* 5/1960 and 8/1960), which reached its climax with the successful flight trials of the experimental SC.1 aircraft. It is not surprising that the Belfast firm, with its rich experience based on the evolution of the SC.1, is continuing with the further development of this aircraft and has submitted designs to the British Government for a single-seat VTOL combat aircraft capable of flying at supersonic speeds. During the 21st SBAC Show at Farnborough, Short exhibited various models of VTOL combat aircraft, which indicated quite accurately the lines the company is following in its advanced development work.

Interavia understands from a reliable source that the Short factory is working primarily on a single-seat aircraft with a double delta wing, whose prototype would undergo flight tests in about 1963 and become operational a year later. This VTOL will employ the proven steering and stabilization system of the SC.1 and will be powered by six light lift jets (probably Rolls-Royce RB.162s with a thrust-to-weight ratio of 16:1) for vertical flight and by a single by-pass jet engine with an afterburner for forward propulsion in climbing and cruising flight. The configuration of the aircraft (known under the project designation PD.49) can be seen from the adjoining illustration. At low levels the PD.49 reportedly has a speed of Mach 1 or more, and at altitudes above 50,000 ft a speed higher than Mach 2. This aircraft evidently accords with British Ministry of Aviation specifications.

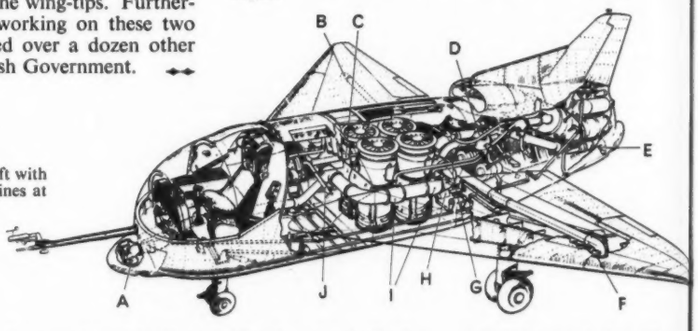
Another delta design worked out by Short includes two vertically mounted lift jets in the forward fuselage and four swivelling lift and thrust engines in pods at the wing-tips. Furthermore, Short is not only working on these two projects, but has submitted over a dozen other VTOL designs to the British Government. ↔



Short PD.49: a single seat combat VTOL aircraft with a double delta wing and six lift jets as well as a thrust engine.



Short design for a single-seat VTOL combat aircraft with two lift jets and four swivelling lift/thrust jet engines at the wingtips.



Cutaway view of the Short SC.1 experimental VTOL aircraft. A – jet nozzle for pitch and yaw stabilization; B – nozzle for roll stabilization; C – air distributor for pneumatic accessories; D – distributor, auxiliary services; E – jet nozzles for pitch and yaw control; F – jet nozzle for roll stabilization; G – air start lines; H – autostabilizer unit; I – lift engine bleed chamber; J – air bleed pipe.

Dassault VTOL Mirage

There are two methods of developing a vertical or short take-off aircraft: one either starts with a V/STOL powerplant, many of which are now available, and creates an airframe around it, or one takes as a basis a proven aircraft type whose combat performance meets all present-day requirements and then attempts to build into it VTOL or STOL characteristics. For those firms who do not have a suitable aircraft available and must more or less start from scratch, the first method is the only possibility. On the other hand, manufacturers who have already developed a proven Mach 2 aircraft will prefer to adapt the existing airframe. Naturally this depends on whether the model serving as the point of departure is suitable for transformation into a VTOL or STOL aircraft.

GAMD (Général Aéronautique Marcel Dassault) possesses such a model in the *Mirage III*. The feature which favours its development into a VTOL or STOL type is primarily its delta wing, which possesses both a large area and light structural weight. These large surfaces enable the *Mirage III* to be exceptionally manœuvrable in subsonic low-level flight and in supersonic flight at high altitude.

Thanks to the increasing chord at the root, the large wing prevents the lifting jets (which are built into the fuselage) from ingesting their own exhaust gases, which would raise the temperature of the air passing through the intakes. The report that GAMD was preparing a VTOL version of the *Mirage III* was therefore not a great surprise to the technical world.

Dassault, like Lockheed, Short and other firms, decided upon separate lift and thrust engines, in contrast to designers who used the same engine for both lift and forward propulsion. When Western military staffs began to show interest in both formulae of the major British engine manufacturers, the lift and thrust motoproposed by Bristol seemed rather to suit the requirements of subsonic flight, whereas the solution suggested by Rolls-Royce for supersonic flight contained within itself a method for converting existing conventional aircraft for VTOL. This is doubtless one of the reasons behind the GAMD concept. The formula selected has further advantages as well, which Rolls-Royce expressly points out: a single engine, whose thrust suffices for a short or even a vertical take-off, develops too much power for cruising flight, and the weight of its fuel exceeds the weight of special lift engines. Within recent months the development of thrust and lift engines has undergone great advances. It now appears possible to insert an afterburner into the gas stream from the jet nozzles. This increases the thrust of the bypass engine to a point where speeds greater than Mach 2 can be obtained. Thus one major objection to the lift/thrust powerplant disappears. Nevertheless, the superiority of the separate lift and thrust engine in respect of fuel consumption and in operational safety remains unexcelled. ↔

Dassault Balzac

A few months ago Générale Aéronautique Marcel Dassault was told by the French Government to go ahead with the development of a prototype of a VTOL single seat combat aircraft. This prototype (called the *Balzac*) is derived from the original model 001 of the *Mirage III*, and for forward propulsion employs an advanced Bristol *Orpheus* engine. For hovering and VTOL purposes Rolls-Royce RB.108s will be provided, arranged in groups of four on either side of the *Orpheus* air intake.

After choosing the method of propulsion, Dassault had to decide on building a STOL or a VTOL. Actually, from the purely theoretical standpoint, vertical take-off with sufficiently powerful lift engines is now a definite possibility. In practice, however, special platforms are needed for vertical take-off, to withstand the hot efflux.

What is more, operational requirements only rarely demand an absolutely vertical take-off, for too much fuel is dissipated in the process. Consequently, the "near vertical" take-off is preferable, in which the aircraft leaves the ground after a short run, moves into steep climbing flight supported by its lift engines, and on attaining the necessary speed continues to ascend in conventional wing-borne flight, propelled only by its cruising engine. In deciding on the length of the take-off site, only a few yards need be allowed for the take-off run, and a few dozen yards to permit clearance of a 50 ft screen. In contrast to this, Dassault speaks of short take-off if the take-off run amounts to some tens of yards, and under certain circumstances to over 100 yards.

After exhaustive investigation of a project built around lift jets, the Dassault engineers arrived at the optimum procedure of a "near vertical" take-off. As trials with the SC.1 have shown, even slight forward motion with lift engines in operation is enough to reduce surface erosion and prevent recycling and the ingestion of foreign bodies. Further, there is no real obstacle to an increase in loading—either fuel or weapons—because the same aircraft, depending on its loading, takes off either at a "near vertical" angle or in more gradual horizontal flight from a longer runway.

According to a bulletin recently published, SNECMA intends to build light lift engines, like those which have been under development at Rolls-Royce for the last five or six years. At the same time, the French engine company announces the development of a fan engine which is directly derived from the Pratt & Whitney JTF-10. It must be recalled that the JTF-10 was originally destined for the Douglas DC-9, and later chosen as the powerplant for the Douglas *Missileer*, an aircraft designed to carry guided missiles. The French version of the JTF-10 is to be more powerful than the original model and will include an afterburner. There is talk of its powering all future versions of the *Mirage IV* and *Mirage III*, including the VTOL version of the latter.

Some data about the projected VTOL can be deduced from this information. The take-off weight of the present *Mirage III* is between 8 and 10 tons, depending on its mission; to this can be added the weight of the lift jets, fuel, and a new navigation and fire control system which will doubtless be far more complex than the type in current use. In consideration of the general trend towards increasing weight, it can be safely assumed that the VTOL version will be at least 10 percent heavier. This amounts to a take-off weight of 9 to 11 tons; for such a weight a vertical thrust of 13 to 15 tons is needed. The lift-to-weight ratio of 1.4 assumed here should be sufficient for Central European climatic conditions. Hence six lifting jets of 5,500 lb thrust will be required for a 9 ton aircraft, or eight of 6,600 lb for an 11 ton aircraft. The larger number would be preferable, as it would contribute markedly to better flight safety. If one of the eight engines should fail, stable hovering flight could be maintained by switching off the corresponding engine of the opposite side. This hardly seems possible with six engines, if an uneconomically high power surplus is to be avoided. Furthermore, the distribution of lift makes possible longitudinal stabilization with the aid of the lift engines themselves. This was proposed by Rolls-Royce, in a clear reference to the immediate response of its lift jets.

As far as forward propulsion is concerned, the SNECMA fan engine yields about 6 tons of thrust dry, and more than 8 tons with an afterburner. Because of the ducted fan, the diameter of the new engine doubtless exceeds that of the *Atar*, and though the lift jets enlarge the cross-section and the surface of the fuselage, the additional drag is more than compensated for by the 30 percent increase in thrust. In other words, the maximum speed should lie considerably higher than Mach 2.3, so that the VTOL *Mirage III* is already close to the heat barrier.

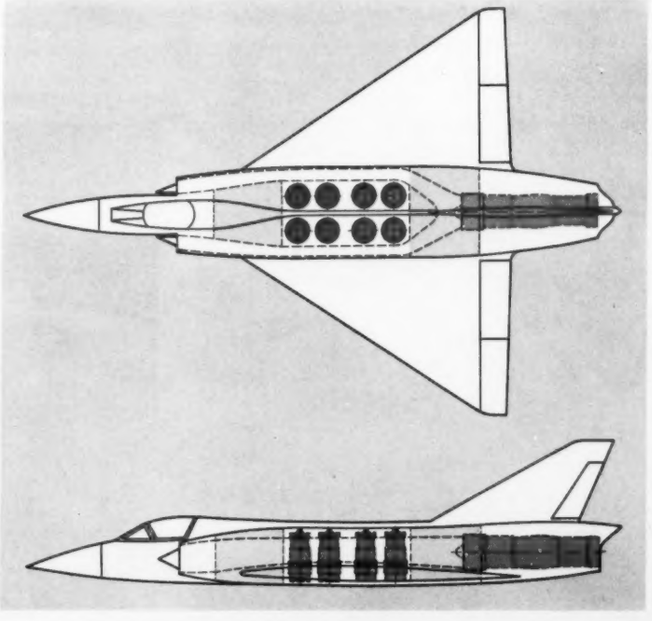
Nothing is known at present of the missions which the VTOL *Mirage* would undertake. But on the basis of similar projects under way in other NATO countries, it is probable that the main emphasis will rest on low-level missions. After penetration under the enemy radar screen, moving targets on the ground would be attacked, while fixed targets would be reserved for tactical guided weapons. On the other hand, the VTOL *Mirage*, with its speed of more than Mach 2 and a correspondingly high maximum ceiling, could be used to identify and attack aircraft intruding at great heights. Thus, even in its VTOL project, GAMD has adhered to earlier lines of development.

By developing this model directly from its predecessor, GAMD has systematically improved performance and is now following the line best calculated to build VTOL characteristics into the tried and tested *Mirage*. ◆◆

The evolution of the Mirage

Model	Mirage I (M.D. 550)	Mirage II	Mirage III 001	Mirage III A	Mirage III C	Mirage III VTOL
Length Wing span Wing area	— — —	— — —	41 ft 25 ft 312.1 sq. ft.	44 ft 26 ft 5 in. 376.7 sq. ft.	44 ft 26 ft 5 in. 376.7 sq. ft.	45 ft 31 ft 2 in. about 376.7 sq. ft.
Take-off weight	about 5 tons	—	—	6-7 tons	8-10 tons	9-11 tons
Engines	2 MD 30R *Vipers** 1,650 lb each without afterburner; 2,156 lb each with afterburner	2 Turboméca *Gabizos* 2,420 lb without ab; 3,300 lb with ab; SEPR rocket motor	1 SNECMA *Atar 101G* 5,500 lb without ab; 9,768 lb with ab; later with 1 SEPR-66 rocket motor of 6,600 lb	1 SNECMA *Atar 9* 14,080 lb with afterburner; later 1 SEPR-841 rocket motor of 3,300 lb	1 SNECMA *Atar 9C* 14,080 lb with afterburner; 1 SEPR-841 rocket motor yielding 1,650 or 3,300 lb	1 SNECMA (advanced P & W JTF-10), 13,300 lb without ab; 17,600 lb with ab; 8 light lift jets of 4,400 lb each or 6 light lift jets of 5,500 lb each
Maximum speed	—	—	Mach 1.5 without rocket motor; Mach 1.9 with rocket motor	Mach 2+ without rocket motor	Mach 2.3	More than Mach 2.3
First flight	25.6.1955	never	18.11.1956	12.5.1958	9.10.1960	?
Used for	Light interceptor	Light interceptor (abandoned before construction of first prototype)	Prototype of *Mirage III C* single-seat fighter	Previous series of *Mirage III C* single-seat fighter	Multi-purpose aircraft with independent navigation and fire control systems	V/STOL combat aircraft for attacks against ground targets, interception, air zone security, etc.

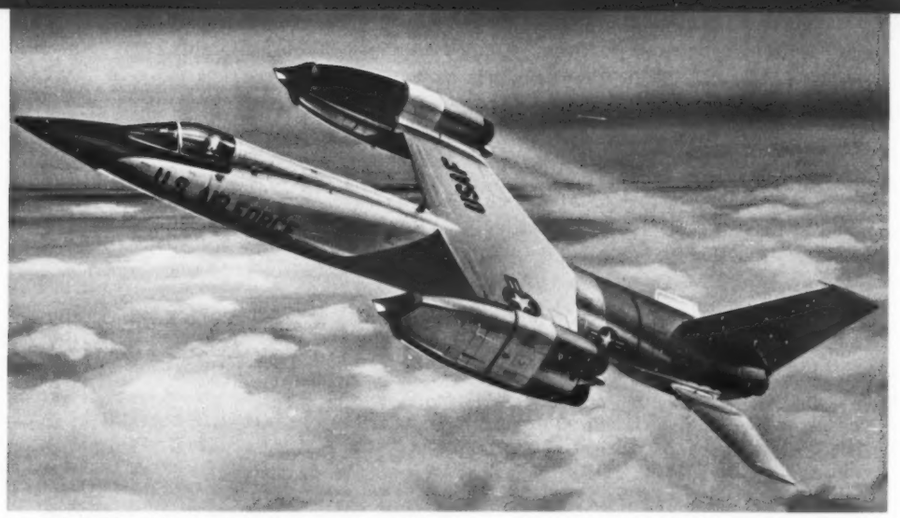
* *Licensed by Armstrong-Siddeley.* *ab=afterburner.*



A VTOL version of the *Mirage III* single-seat combat aircraft, with a conventional engine at the rear and eight lift jets in the middle of the fuselage, might look like this (*Interavia* drawing).

V/STOL

The Bell D-188A



The Bell D-188A with wing-tip engines in cruise position.

Among the first exponents of vertical take-off with the aid of swivelling jet engines is doubtless the firm of Bell, which some years ago built a prototype to investigate stabilization and engine behaviour in a VTOL aircraft. Subsequently, under a joint USAF and U.S. Navy programme, the Aerosystems Division of Bell Aerospace Corporation received a contract for the design and development of a single-seat multi-purpose combat aircraft. Designated Bell D-188A, this aircraft was to be fitted with eight General Electric J85 light jet engines for vertical lift; six of these would also be used to achieve speeds of the order of Mach 2.3 in level flight. Although it does not at present appear that the American armed services are still interested in further development and quantity production of the D-188A, this unusual design nevertheless merits attention, as the supersonic VTO combat aircraft design of Entwicklungsring Süd, of Munich, is also based on the use of swivelling jet engines.

The pictures of the full-size D-188A mockup, published here for the first time, give an idea of the aircraft's configuration and certain structural details. The short, straight knife-like wing has inboard spoilers for lateral control and should produce minimum drag in supersonic flight. Two J85 jet engines in swivelling double pods are mounted at each wingtip. The intake diffusors of these jets have a projecting boundary layer fence.

As the jets are rotated to a vertical position for take-off and landing, a slot is opened between the engine pod and intake, enabling the compressor to obtain an increased quantity of air. In the rear of the slim, wasp-waisted fuselage (supersonic area rule) are installed two J85 jets whose jet pipes can be deflected slightly downwards for vertical take-off. Two further J85s are installed vertically in the fuselage nose directly behind the cockpit. These are used only during the vertical phase, their intake and exhaust openings remaining closed during cruise.

According to Bell, the D-188A can take off and complete the transition phase in 60 seconds; the transition from forward to hovering flight and the subsequent landing can also be made in a minute. The aircraft is, of course, also suitable for short take-off, for which it is first accelerated by the four wing-tip engines (in a horizontal position) and the two rear engines. After the aircraft has rolled for a certain distance, the four wing-tip engines are swivelled to supply additional lift by adding a vertical thrust component.

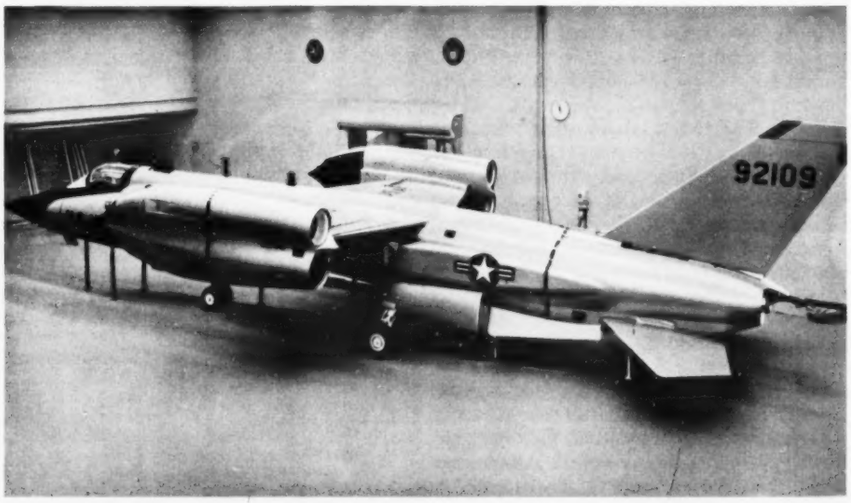
The pilot has only two controls to actuate, one for the wing-tip engines, the other for the four engines in the fuselage. The wing-tip engines can be swivelled by actuating a thumb switch on the control column. During take-off, the wing-tip engines function with reheat at continuous thrust, while the engines in the fuselage can be regulated by the pilot to give the desired rate of climb. During the hovering phase, the aircraft is yaw and roll stabilized and controlled by bleed air from the engine; pitch stabilization and control are achieved by adjusting the respective thrusts of the front and rear fuselage engines.

The maximum speed in level flight has been calculated as Mach 2.3 though it should be possible to reach speeds of the order of Mach 2.5 in dive. The normal cruising range for subsonic flight is approximately 1,000 miles, the combat ceiling 67,500 ft, and the sea level rate of climb over 61,000 ft/min. Fuselage length is 58.6 ft, span (including engines) 23.8 ft, and design gross weight 25,000 lb. The fuel supply of almost 5 tons is carried in the fuselage.

The D-188A would make use of engines and equipment at present available on the market, so that it could be ready for operational service in a very short time.

Mockup of the D-188A with wing-tip engines turned downwards.

The air intakes for the rear engines can be seen at the side of the fuselage behind the wing. Under the fuselage are two additional fins to improve directional stability.



VTOL Version of the F-104

The Lockheed Aircraft Corporation has studied and proposed VTOL aircraft of all types and configurations for many years. One design which was built and flown was the U.S. Navy XFV-1 fighter, which was one of the United States' efforts during the era of experimentation with "tail sitter" configurations. Today, "tail sitters" are not considered satisfactory, though in its day the XFV-1 was one of the most important U.S. contributions to the development of VTOL.

Since that time, it has become apparent to all that the conventional horizontal take-off attitude is necessary. Special purpose lift engines of very high thrust-to-weight ratios are now available for vertical take-off; these can be clustered together in a small space in lift pods, their low height enabling them to be mounted at the wing-tips like auxiliary fuel tanks. This configuration has been studied in detail by Lockheed and has evolved into a concrete proposal for the application of two wing-tip lift pods to give the multi-mission Lockheed F-104 effective VTOL capabilities.

Lockheed considers that a 5 percent minimum excess of thrust over weight is sufficient to give the pilot the necessary lift-off response he desires to establish his vertical ascent rate with full control for the most stringent conditions. This is on the assumption that the lift jets themselves can be used to control the aircraft about all three axes.

Table I lists the thrust requirements for the phases of a tactical mission for a typical current multi-purpose fighter, expressed as percentages of take-off weight. These data indicate that the horizontal propulsive thrust required for supersonic combat and subsonic cruise at 35,000 ft is 60 percent and 12 percent respectively of the aircraft take-off weight. To obtain the optimum combat radius of action it is usually essential to provide a horizontal propulsion engine of such a size that the minimum specific fuel consumption is obtained at a thrust corresponding to that required in the cruise condition. It can be seen that the thrust available is sufficient for all requirements except for vertical take-off. Further increases in engine size to satisfy the vertical take-off requirement would be detrimental to fuel economy in cruise and reduce radius of action.

A logical solution to this problem, therefore, is the utilization of a separate propulsion system for lift augmentation during take-off and landing. A critical comparison of this concept with the many other proposed methods of obtaining the required additional thrust for VTO operation has indicated that for the multi-mission fighter, separate lift engines result in a smaller, lighter vehicle than any other system.

Operational aircraft safety should be equivalent to that of current conventional fighter types flying today. The failure of a lift engine must not therefore preclude safe, controlled flight to the nearest suitable landing area. Here it suffices to consider a single engine failure, the failure of two engines at one and the same time being somewhat improbable.

Using the probability equations, calculations show that a double engine failure can be expected only once in over 200 million take-offs for a four-engine aircraft, once per 30 million take-offs for a 10-engine aircraft, and once per 7 million take-offs for a 20-engine aircraft. The probability of a double engine failure is so remote that a relatively large number of engines are acceptable.

Emergency power ratings for present-day powerplants amount, on average, to 110 percent of the normal rating in the case of non-afterburning engines. It is not considered advisable to fit lift jets with afterburners because of ground erosion, site and structural problems, and the time lag and light-up reliability characteristics of

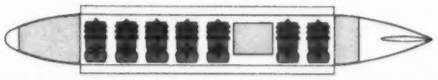


Fig. 2: Diagram of the pod proposed by Lockheed. The light-grey areas indicate the position of the fuel tanks, the engines are shaded in dark grey.

such a system. In the case of an engine failure, it is assumed that the remaining engines can be operated at an emergency rating of 110 percent to provide safe landing and compensate for the loss of lift, with adequate allowance for vehicle stability and control. It is evident, therefore, that a minimum of 10 to 14 engines should be considered and that less lift engines cause either reduced safety or greater weight penalty than necessary.

Altitude and attitude control requirements in hovering and low-speed flight depend on the amount of automatic stabilization assumed operative under the worst conditions. For reasons of tactical efficiency, automatic stabilization is a design requirement for normal aerodynamic flight, but manual control must also be provided in the event of automatic system failures.

For the typical design considered here, accelerations in pitch and yaw of 20°/sec² and in roll of 50°/sec² are necessary. These accelerations require very large control moments as compared with those which have been provided in most experimental VTOL machines to date. These large control moments are necessary for safety and ease of operation by the average pilot under varying weather conditions. Such moments are easily obtained when the lift engines are located sufficiently far from the aircraft centre of gravity. Thus, lift engine thrust modulation can be used to provide finely tuned stabilization and control forces in the hovering and transition phases.

Table I : Available and Required Thrust

Flight phase	Thrust of main engine as a percentage of take-off weight: required	available
Vertical take-off at design altitude and temperature	105 %	55 % (with reheat) 35 % (without reheat)
Cruising at Mach 2 and 35,000 ft	60 %	62 %
Target approach at Mach 0.9 and 35,000 ft	12 %	13 %
Loiter	7 %	35 %

Description of the project

The set of firm requirements just described has been incorporated in all of the extensive VTOL design studies done at Lockheed. Lift engine development is now such that a unit producing a thrust of about one tenth of the gross weight of the VTOL vehicle at take-off is very small in diameter and length.

An example of wing-tip lifting pods is shown in *fig. 1*. In this figure, the concept is depicted in its application to the F-104 aircraft, although the principle is equally attractive for completely new fighter designs. Basically, the fighter is designed for supersonic multi-mission capability; the lift pods are simply added for vertical take-off and landing, including transition flight. The concept offers the following advantages:

1. The crew and aircraft systems required to accomplish the mission (radar, fire control, communication, navigation) and the propulsive engine are located in the fuselage.

2. Very large lifting moments can be obtained during hovering and transition flight owing to the rapid reaction time of the lift jet thrust control.

3. All the accessory power and bleed air requirements are supplied by the fuselage-located propulsive engine.

4. The lift engines are utilized purely for the jet thrust required for low-speed flight only. The required high value of thrust-to-weight ratio is not compromised by secondary considerations.

5. The lift engines are mounted without external ducting or extensions. The entire unit is inside the pod and can be easily inspected and maintained.

6. Although the lift pods are designed for maximum lift engine efficiency, they are of the ideal aerodynamic shape for minimum supersonic drag.

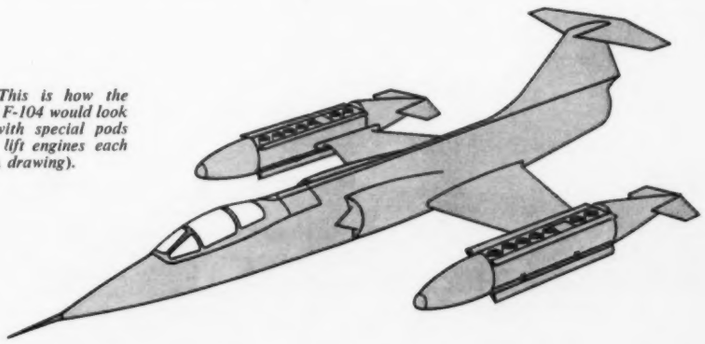


Fig. 1 : This is how the Lockheed F-104 would look if fitted with special pods for seven lift engines each (Interavia *drawing*).

7. If normal runways are used, the lift pods can be rapidly removed and replaced by armament or large fuel tanks for extended range.

The lift pod design is shown in *fig. 2*. The engines are so mounted that the resulting thrust lies along the aircraft's lateral axis; this eliminates undesirable longitudinal moments. Additional fuel tanks are housed in the pod. The lift engines operate independently of equipment external to the pods, with the exception of control inputs and starters. Fuel can be transferred between pod tanks and fuselage tanks.

*

The operation of the pod can be described as follows:

1. There are a sufficient number of lift engines installed to meet the design conditions of lift, control and engine inoperative safety.

2. By varying the thrusts of the left and right, front and rear engines, the aircraft is maintained in pitch and roll trim for centre of gravity variations and for engine inoperative conditions.

3. Transition acceleration and deceleration is obtained by symmetrical fore and aft deflection of swivel nozzles on the lift engines.

4. Yaw control in jet-borne flight is obtained by asymmetric deflection of the engine nozzles in the left and right pods.

5. Additional pitching moment for control must be obtained from the propulsive engine in the designs that have been studied.

The lift engine thrust and swivel nozzle control will be linked to the conventional aerodynamic controls of the aircraft, so that manual or autopilot commands which actuate the aerodynamic controls will also actuate the low-speed flight reaction controls.

Advantages of the chosen engine configuration

Before it was decided to mount the lift engines in wing-tip pods, Lockheed investigated a variety of other engine layouts. It was found that the available lift was increased by moving the jets to the wing-tips. A ground effect is created similar to that obtained from hovercraft, and this aerodynamically increases the lift generated by the engines. This increase in lift as the distance to the ground is reduced is a highly desirable characteristic of the engine layout chosen, as it increases stability.

During the transition to and from conventional wing-borne flight, the normal aircraft aerodynamics are affected to some degree by the flow field produced by the vertically issuing jets. The effect of the jet is to increase pressure on the bottom surface of any body ahead of the jet, and reduce pressure behind, thus producing a variable nose-up pitching moment during the transition phase. It is readily apparent that this can be an important factor for centre-located engines and a negligible factor for tip engine design.

The lift pods in the wing-tips provide certain advantages with regard to hovering and low-speed control. The large control moments necessary to stabilize a VTOL aircraft during hovering must be obtained either by the use of compressor bleed air ducted from centrally mounted engines to the aircraft extremities, or by the use of direct engine thrust for peripherally mounted engines. In both cases the engines must supply excess thrust. Since, however, the thrust available from compressor bleed is only a fraction of that obtained for the same pound of air having completed the gas turbine cycle in the form of direct jet thrust, the tip-mounted pods provide an obvious advantage.

The transition from vertical to horizontal flight and back has been a critical manoeuvre in most VTO aircraft flown to date. Analysis indicates that aircraft with separate engines to generate lift and thrust are less sensitive to control errors. With this system, horizontal thrust can be employed to obtain horizontal speeds above the aerodynamic stall without affecting the lifting system. In configurations where the horizontal propulsion system is also employed for vertical lift, care must be taken to ensure adequate vertical lift below the aerodynamic stall speed. A separate lift system is therefore not only less sensitive to error, but also results in reduced time for acceleration and deceleration, with consequent reductions in fuel consumption.

Precise, rapid thrust control is no problem with small, simple lift engines with low rotor inertia.

*

In the view of Lockheed Aircraft Corporation, the configuration of the F-104 multi-mission fighter can easily accept such lifting pods while retaining the existing and proven airframe, fire control and communication and navigation equipment. In addition, the automatic stabilization and flight control system can be retained for operation in the hovering and low-speed flight regimes. Existing fighter-bomber, interceptor and ground attack armament can be used, together with reconnaissance equipment already being developed. Since minimum operating site preparation is needed, the requirements for mobility and dispersal would be amply fulfilled.

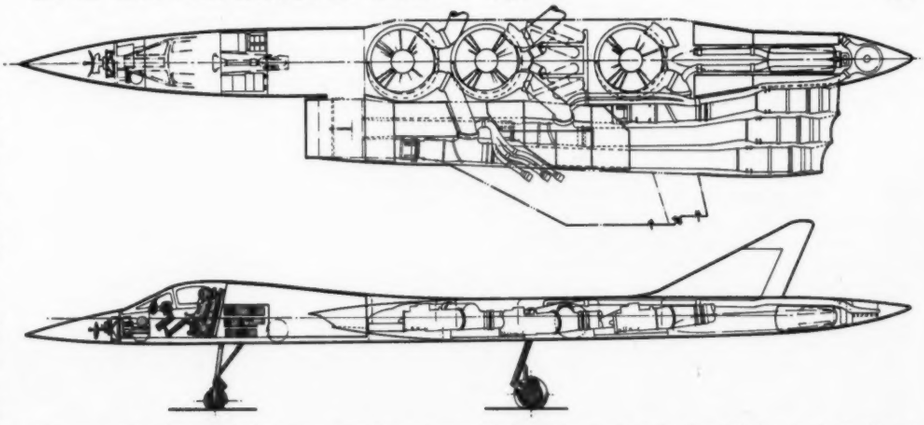
If a rudimentary concrete runway is available for a short take-off or landing run, the permissible take-off weight can be increased or a higher airfield used. ◆◆

Republic VTOL Projects

Under a five-year V/STOL research programme which has cost some $5 million, Republic Aviation Corporation has developed an all-weather VTOL fighter-bomber with variable-sweep wings. This meets the USAF Tactical Air Command SOR 183 specifications and incorporates a number of further innovations which will be reported on in a later issue of *Interavia* Review.

Parallel with this project, Republic and its European associate Fokker are developing a fighter-bomber with VTOL capability to meet NATO requirements; this would also be an all-weather model and would fly at higher supersonic speeds. A conference of representatives of both companies, attended by Alexander Kartveli, Republic Vice-President of Research and Development Engineering, was held in Amsterdam in December to discuss the joint development of this VTOL project.

Independently of this programme, Republic engineers have been investigating the use of General Electric lift fans for a supersonic fighter-bomber and have evolved project AP-100, illustrated in the accompanying diagrams. This is a single-seat fighter-bomber with a wing span of 33 ft 6 in., a length of 67 ft 9 in., and a take-off weight of 38,000 lb, powered by six General Electric J85 jets with three centrally located lift fans for vertical take-off. The fans would be driven by the exhaust gases from the six jet engines, each of the three fans delivering a vertical thrust of 14,400 lb with the engines working at full power. A longitudinal thrust vector would be generated during the transition phase with the aid of a jet deflection louvre beneath each lift fan; this thrust would accelerate the AP-100 in level flight until the lift fans had fully shut down. General Electric has fully tested the diverter valve to direct the hot gas flow to the fan or the afterburner (cf. article on pp. 96-97). Although this project now appears to have been abandoned, it presents interesting possibilities to military experts. ◆◆



Diagrams of Republic's AP-100 project with delta wings and twin rudder. Each of the three lift fans in the fuselage is supplied with exhaust from two J85s (one to starboard and one to port); the exhaust in its turn drives the turbine blades around the rim of the fan. When the fans are shut down, the exhaust is led down long ducts to the fuselage rear, where six afterburners re-accelerate the gas flow. The fuselage rear contains a jet control fan for the vertical phase; further jet control nozzles are at the wing-tips. The nuclear bomb which the AP-100 is designed to carry is suspended in the fuselage rear between the last lift fan and the small jet control fan.

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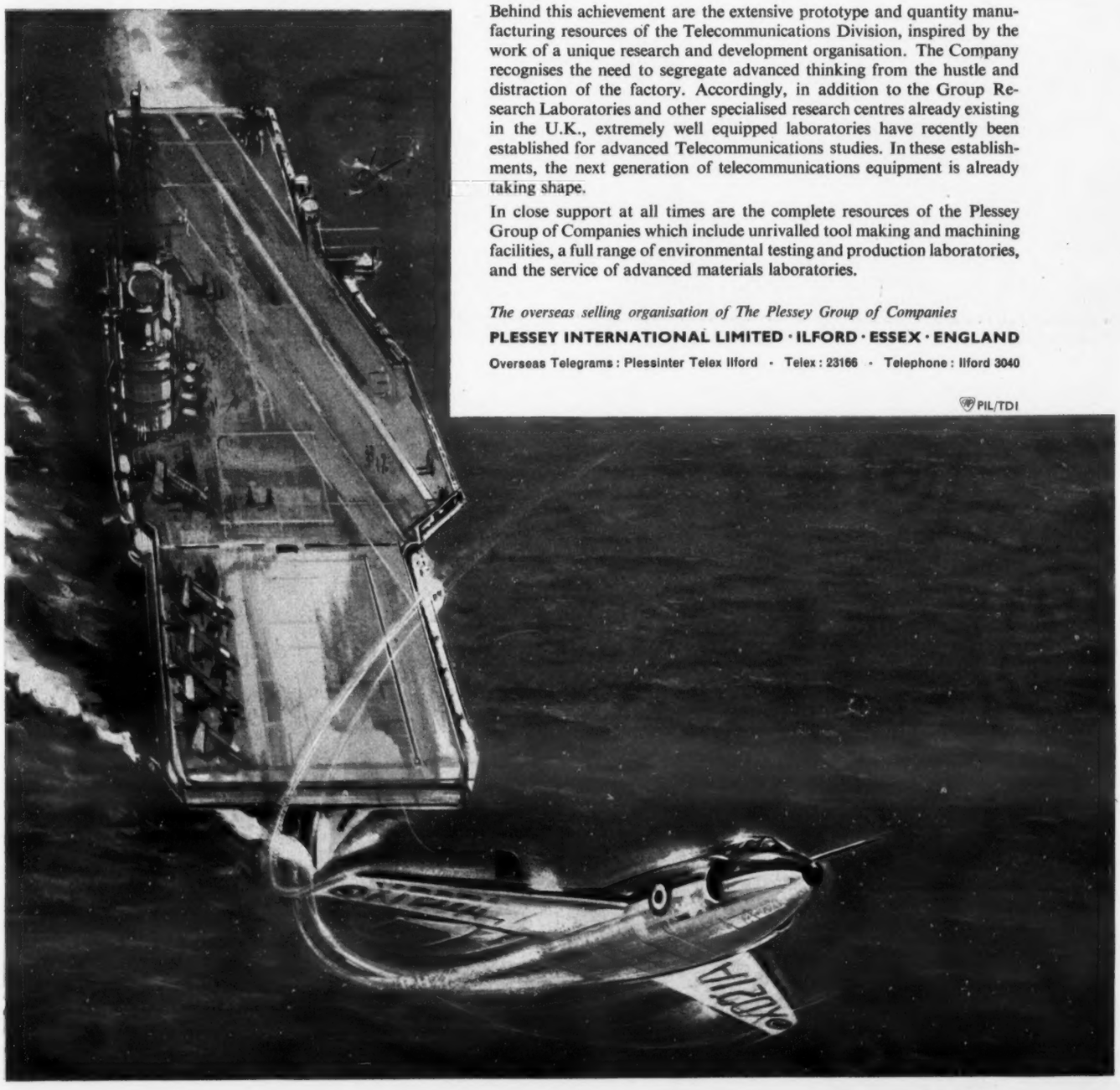

Behind this achievement are the extensive prototype and quantity manufacturing resources of the Telecommunications Division, inspired by the work of a unique research and development organisation. The Company recognises the need to segregate advanced thinking from the hustle and distraction of the factory. Accordingly, in addition to the Group Research Laboratories and other specialised research centres already existing in the U.K., extremely well equipped laboratories have recently been established for advanced Telecommunications studies. In these establishments, the next generation of telecommunications equipment is already taking shape.

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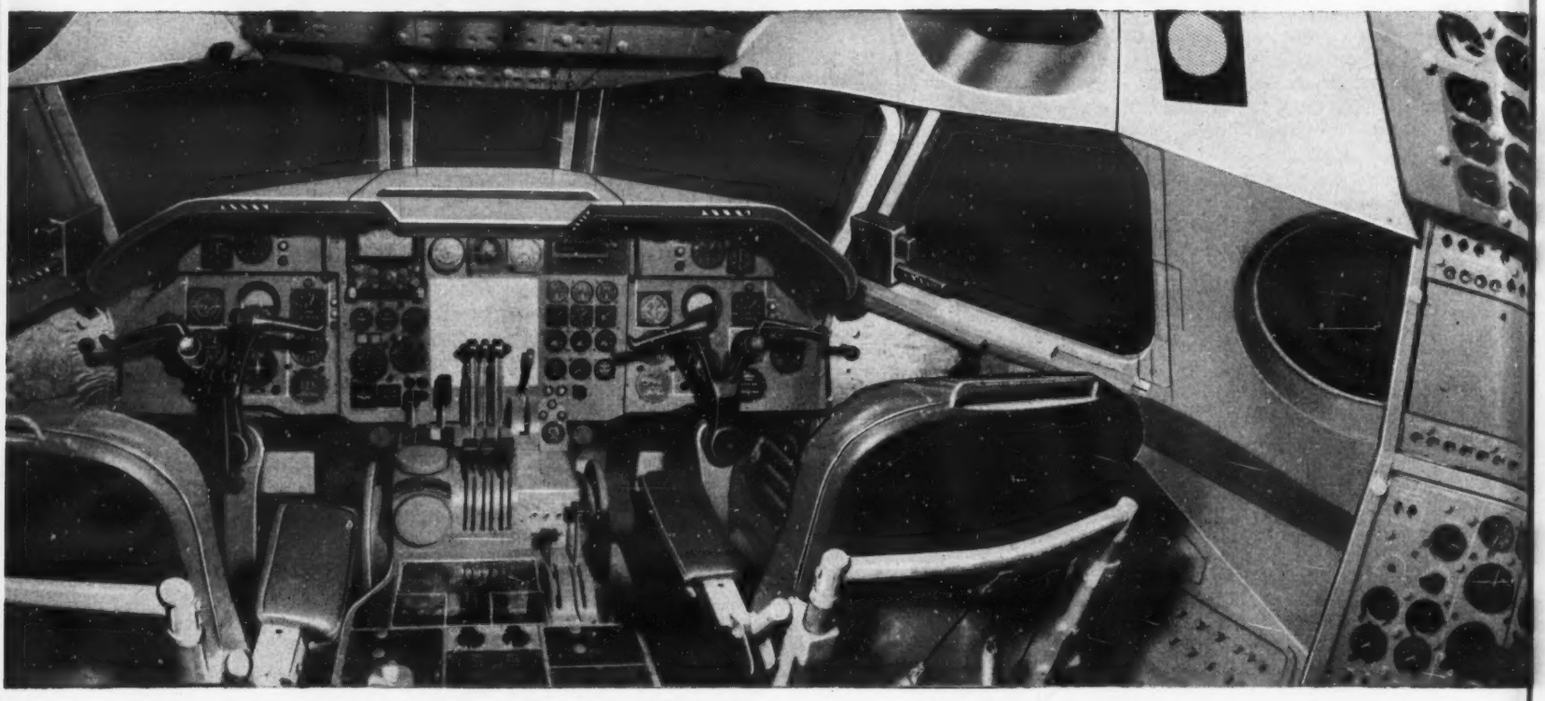

This is a mock-up of the BEA de Havilland 121 cockpit. Smiths equipment has been specified to provide automatic flare control when the aircraft enters service. Smiths S.E.P. 5 automatic pilot (the pilot's controller is in the bottom centre of the picture) operates on the Multiplex principle and will, ultimately, provide full automatic landing facilities to civil safety standards. Smiths Para Visual Director (P.V.D.), a revolutionary flight director display, can be seen around the panel coamings. In the D.H. 121 Smiths P.V.D. will operate in conjunction with the new Smiths integrated Flight System, specifically designed in conjunction with BEA to fit the 121's operational role.

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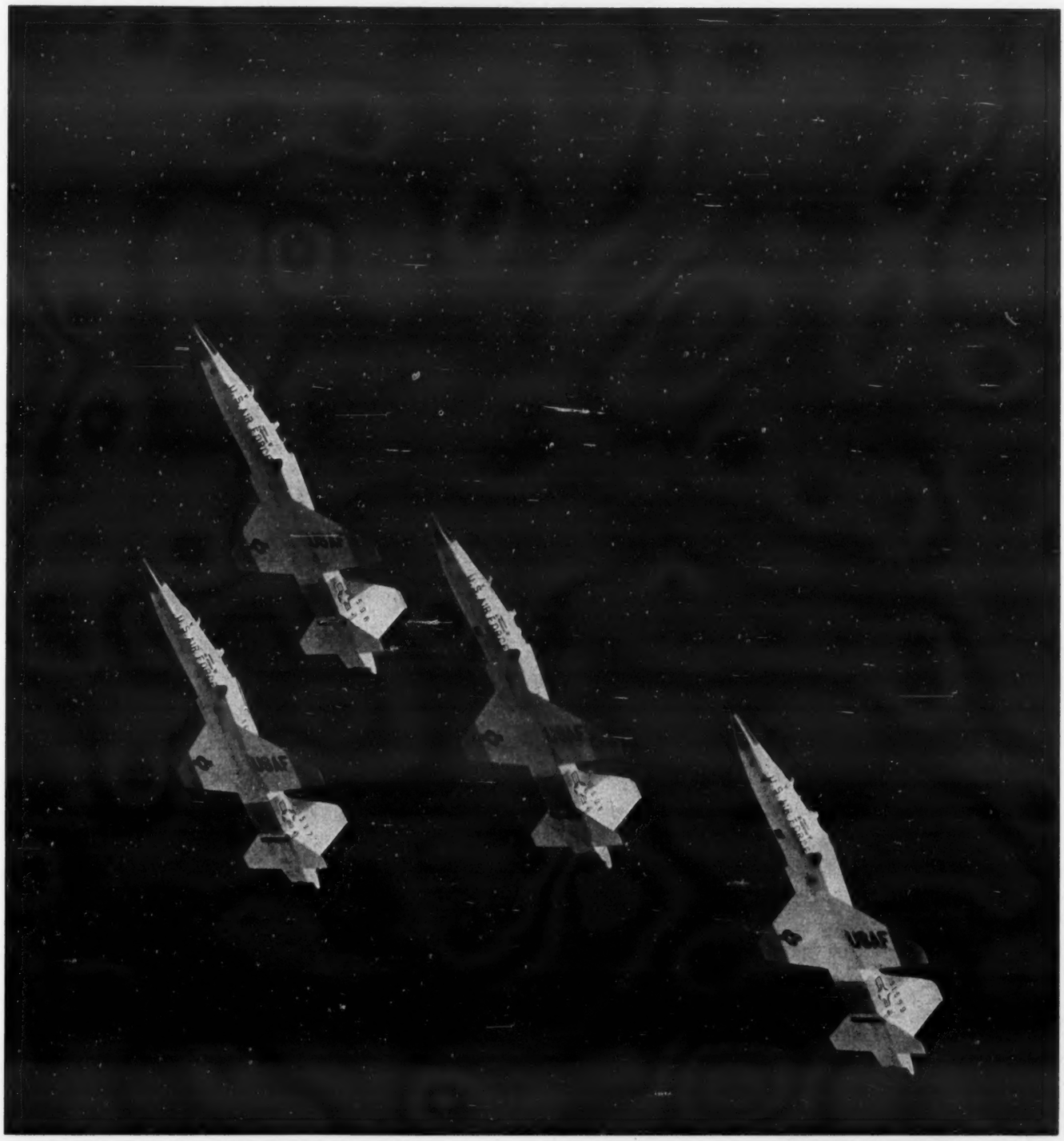

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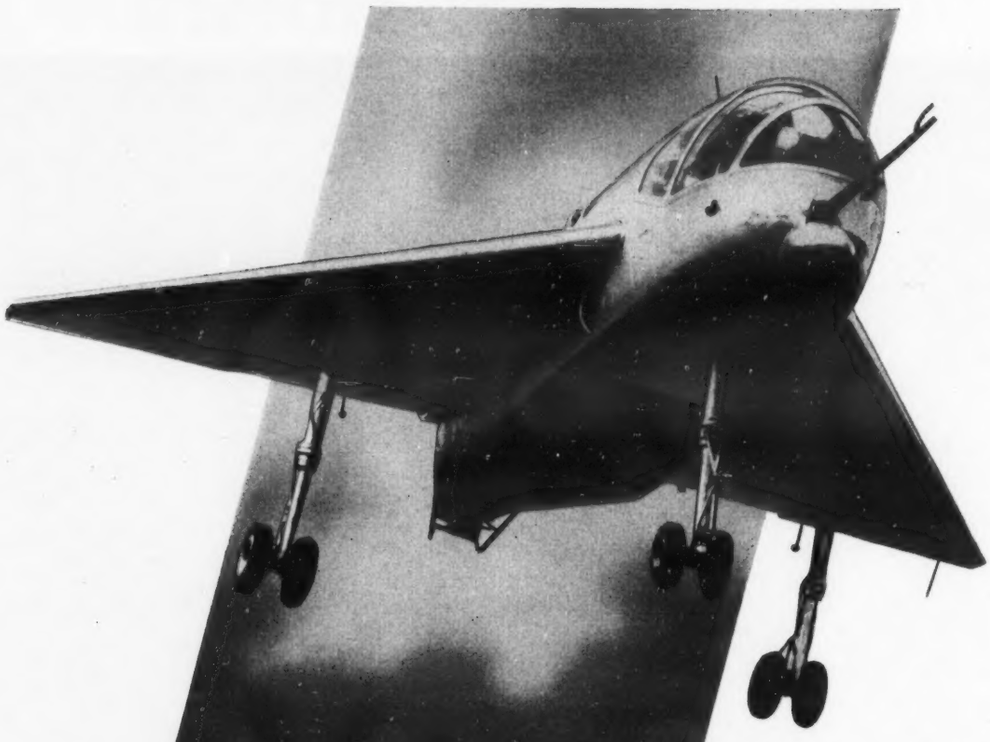
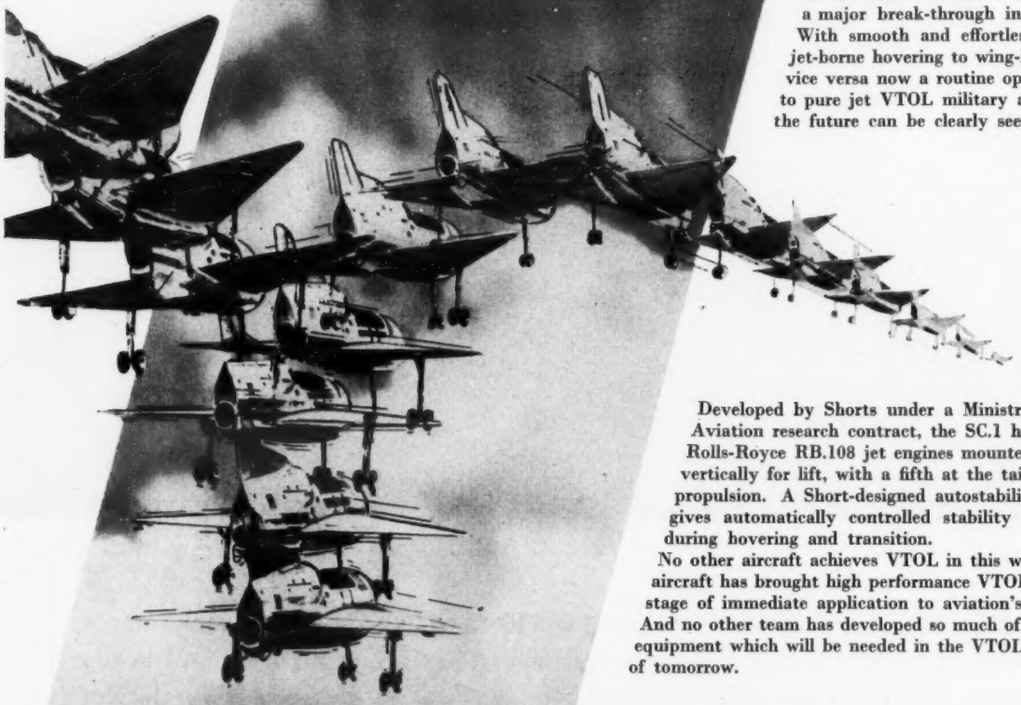


The *Short* SC.1 goes forward

The recent, dramatically successful demonstrations on seven successive days at Farnborough by the Short SC.1 VTOL aircraft proved conclusively to the world that Shorts have achieved a major break-through in aeronautical progress. With smooth and effortless transition from jet-borne hovering to wing-borne flight and vice versa now a routine operation, the way to pure jet VTOL military and civil aircraft of the future can be clearly seen.



Developed by Shorts under a Ministry of Aviation research contract, the SC.1 has four Rolls-Royce RB.108 jet engines mounted vertically for lift, with a fifth at the tail for propulsion. A Short-designed autostabiliser system gives automatically controlled stability during hovering and transition.

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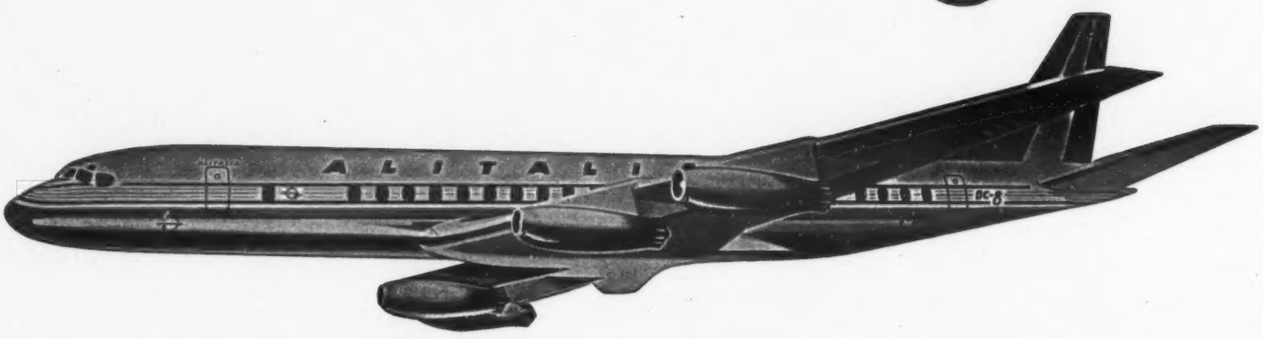

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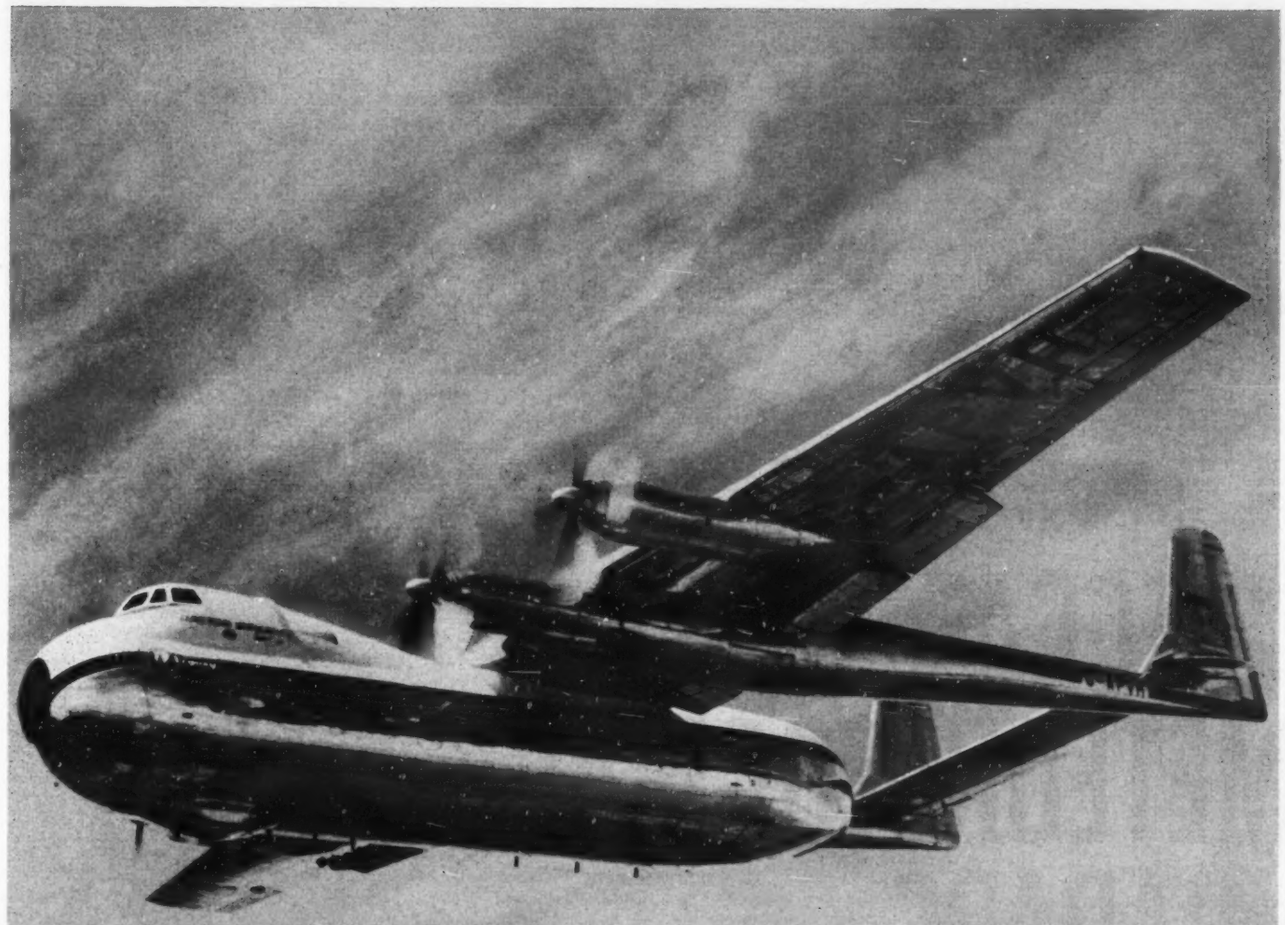

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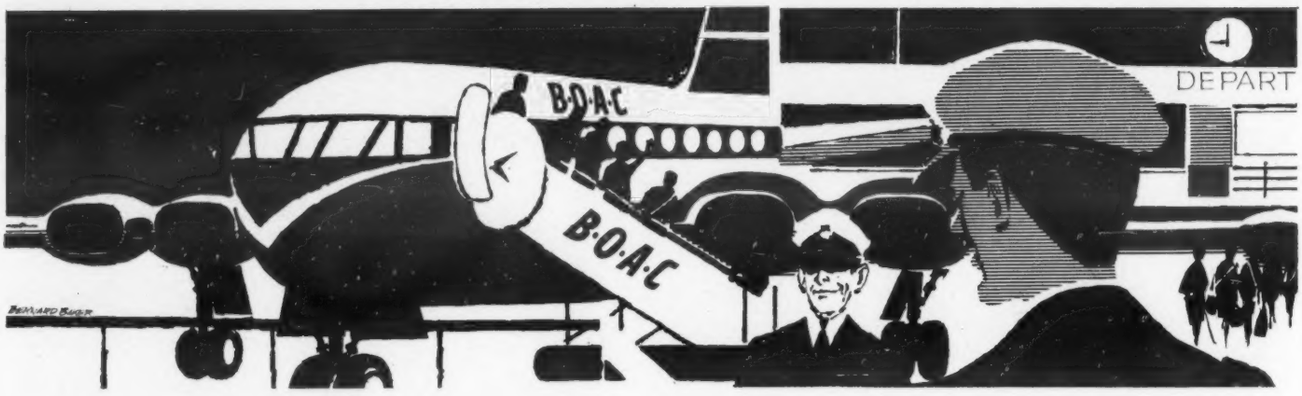

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Design Principles for High Subsonic Speed STOL Strike Aircraft

By Giulio Ciampolini and Franco Giura, Fiat Divisione Aviazione, Turin

Research and development on an STOL strike aircraft at Fiat is proceeding along two parallel lines. On one hand, parametric investigation is being thoroughly explored from the theoretical viewpoint[1], and on the other a progressive improvement is being carried out in practical application.

As its name suggests, the parametric method is of use in determining the influence of certain variable but basic values on take-off weight and take-off distance of STOL aircraft, particularly those of wing loading, thrust-to-weight ratio, maximum lift coefficient and the deflection angle of the jets at take-off.

Here two basic types of propulsive system must be differentiated; we shall call these the *conventional* and the *composite systems*. The choice of type depends primarily on the mission of the aircraft and the acceptable take-off weight. We assume that radius of action and a high subsonic cruising speed are of major significance in the design.

While a conventional propulsive system may include one or more longitudinally mounted turbojets, by composite system is meant a battery of turbojets, in which some of the engines are used to provide thrust at take-off and in flight, while the others operate for short periods to provide the lifting thrust required at take-off[2]. We can show that the weight of a strike aircraft with a conventional propulsive system can rise to approximately double the weight of an aircraft with a composite powerplant if one assumes an average strike mission and presupposes the same thrust to take-off weight ratio (values between 0.7 and 1.1) and the same wing loading. Moreover, the composite powerplant permits a better utilization of the turbojets during the various stages of flight: take-off, cruise, high speed flight, and consequently reduction of the fuel reserves necessary for a particular mission, owing to a considerably lessened specific fuel consumption. Finally, the so called "growth factor" should be noted in this connection: every additional pound of built-in weight or fuel increases the total weight of the aircraft by the well-known multiplier effect by many more pounds.

Fig. 1 shows the results of our comparative calculations. The take-off weight for a particular mission can be read off the vertical axis at the point relative to the selected wing loading and thrust-to-weight ratio.

It must be realized that the take-off performance of the aircraft is not influenced directly by the choice of propulsive system, but depends rather on essential parametric values. The values of wing loading, lift coefficient and thrust-to-weight ratio when considered separately are of paramount influence on the length of take-off distance. When all these parameters are considered in combination, their mutual relationships are more difficult to grasp and to calculate in advance.

Fig. 2 shows certain results from calculations of take-off performance with a composite propulsion system, in which radical as well as moderate values for the various parameters have been considered. It is clear that in the most favourable cases the take-off distance to clear a 50 foot screen lies between 900 and 1,200 ft. To interpret the table correctly, it must be observed that the figures are valid for a take-off speed of 87 knots and a conventional take-off technique.

So as to clarify the conclusions still more, a detailed study of the specific parameters is required. Let us now look at wing loading *(W/S)*: it is clear that the minimum value of wing loading cannot be made dependent on the desired reduction of take-off distance alone, but must also correspond to other flight specifications for the requisite operational use.

However, if the wing loading is established and the greatest possible lift coefficient is ascertained for the present design, the take-off speed can also be calculated—assuming that one has no vertical thrust components as a result of jet deflection.

To ascertain the take-off distance up to a height of 50 ft one must know the radius of curvature of the initial climb path; this can be calculated for aerodynamic (wing-supported) flight according to the well known formula:

$$\frac{1}{R} = \left[1 - \frac{V_s^2}{V^2}\right] \frac{\rho \cdot c_{L\max} \cdot g}{2\dfrac{W}{S}} \qquad 3)$$

Here V indicates the velocity during the "rotation," V_s the stalling speed in the maximum lift condition; the same weight is assumed for both speeds. The equation shows that as the radius of curvature diminishes, the initial flight path becomes steeper as velocity approaches stalling speed. Apart

[1] Cf. the paper "*Parametric Investigation on STOL Aircraft*," read by Professor Giovanni Gabrielli at the V/STOL symposium in Paris, June, 1960.

[2] See *Fiat Patents 7544 and 7545* dated 16th September, 1959.

[3] This series of equations is derived from the balance of forces in the direction of the centre of an assumed circular flight path where L equals lift, (W) is the weight component, and g centrifugal force. The cosine of the climbing angle can be considered to equal 1, yielding:

$$L - W - \frac{W\,V^2}{g \cdot R} = 0$$

$$\frac{\rho}{2} \cdot V^2 \cdot S \cdot c_{L\,\max} - \frac{\rho}{2} \cdot V_s^2 \cdot S \cdot c_{L\,\max} - \frac{W \cdot V^2}{g \cdot R} = 0$$

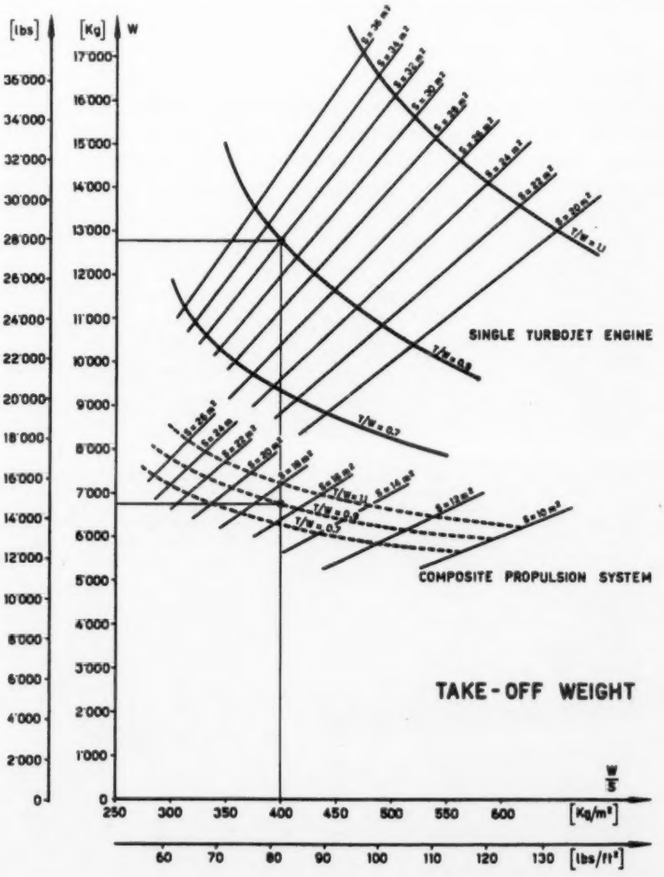
$$\frac{\rho}{2} \cdot S \cdot c_{L\,\max} \left[V^2 - V_s^2\right] - \frac{W \cdot V^2}{g \cdot R} = 0$$

Therefore:

$$\frac{\rho \cdot S \cdot c_{L\,\max} \cdot g}{2 \cdot W \cdot V^2} \left[V^2 - V_s^2\right] = \frac{1}{R}$$

(Editors)

Fig. 1: Comparison between the take-off weights for different missions of strike aircraft with single turbojet engine and composite propulsion system for the wing loading chosen (W/S). Thrust-to-weight ratio (T/W) and wing area (S) serve as parameters.



T/W	Take-off run ft			Take-off distance to 50 ft (ft)			W/S
(——)	$C_L = 1.2$	$C_L = 1.6$	$C_L = 2$	$C_L = 1.2$	$C_L = 1.6$	$C_L = 2$	(kg/m²)
0.7	869	673	623	1,804	1,493	1,329	300
	1,296	1,033	820	2,526	2,067	1,755	450
0.9	459	459	459	1,279	1,132	1,066	300
	689	541	459	1,788	1,444	1,230	450
1.1	377	361	344	1,050	984	902	300
	361	361	377	1,247	1,115	1,050	450

Fig. 2: Table of take-off performances of different STOL aircraft with composite powerplants, with various combinations of thrust-to-weight ratios (T/W), lift coefficients (C_L) and wing loadings (W/S).

from this, the radius of curvature is exclusively determined by the maximum lift coefficient and by the wing loading.

Before we enter into the question of the influence of the thrust-to-weight ratio *(T/W)* once more, it should be stated by way of introduction that this parameter in the case of a STOL is most properly assumed to equal 1 and we therefore assume this value for further observations. Naturally, it is a matter of great importance as to how one employs the available thrust, especially at take-off.

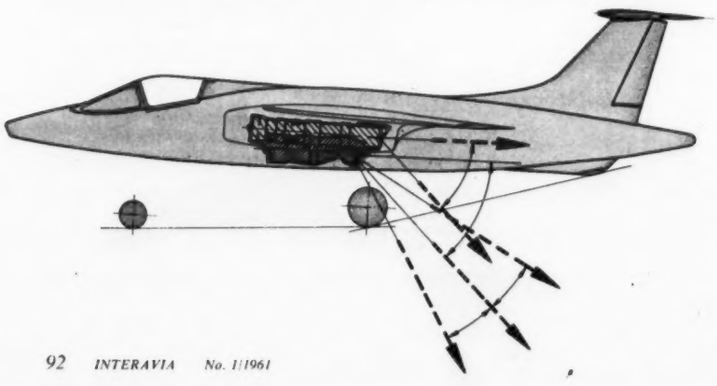
If the total thrust is merely made to work horizontally during take-off, the take-off speed depends exclusively on the aerodynamic lift of the wing, and consequently on wing loading and the maximum lift coefficient. Hence take-off performances would not meet the expectations of a STOL aircraft. Take-off run will surely be shortened considerably as a result of the greater acceleration power available (propulsive plant thrust minus air resistance and undercarriage friction), but the take-off distance to 50 ft will not be affected. The formula cited above is responsible for this, since velocity is correspondingly enlarged.

Essentially better results can be obtained if one component of thrust is employed to reduce the weight and stalling speed. In the extreme case of equality in the vertical component of thrust and weight, the stalling speed and the take-off speed are equivalent to zero. It should be noted that a reduction of the take-off speed considerably shortens the take-off run, roughly according to a quadratic law.

Over the length of the take-off run the application of a vertical thrust component has exactly the same effect as a corresponding reduction of the weight *(W)*, or of wing loading *(W/S)*, i.e., to ascertain the take-off speed one substitutes a fictitious value for the actual wing loading. The conditions are different in the calculation of the curvature of the initial climb course. Here, in addition to the weight components and centrifugal force opposed to aerodynamic lift, the vertical thrust component must also be taken into account in the balance of forces.

Let us consider a numerical example: assume a wing loading of 70 lb/sq.ft., a maximum lift coefficient of 1.5 and a thrust-to-weight ratio of 1. If the thrust is merely made to operate in a longitudinal direction, the take-off speed amounts to 103 knots, the take-off run amounts to 550 ft and the take-off distance is 1,300 ft. However, if the thrust is deflected 45 degrees at the moment of take-off, the take-off speed is reduced to 52 knots, the take-off run amounts only to 150 ft and the take-off distance to 750 ft.

Fig. 4: Diagram of the G.95/2 with two main engines in nacelles (thrust deflectable to 45°) and two auxiliary engines with jet deflection up to 60°. The G.95/2 requires a jet control system for stabilization in the speed range between take-off speed and minimum control speed. The development of an aircraft with a single main engine and two auxiliary engines, but without jet stabilization, is planned as a preliminary stage.



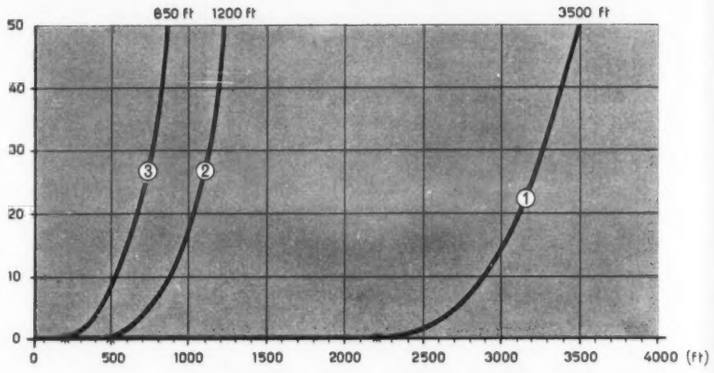


Fig. 3: Comparison of take-off runs and take-off distances to 50 ft, for the Fiat G.91 *(curve 1)*, G.95/1 (first design stage; *curve 2*) and G.95/2 (second design stage; *curve 3*). While the G.95/1 is based on the use of a single main powerplant without thrust deflection plus two auxiliary engines with jet deflection adjustable between 30 and 60°, the G.95/2 will be equipped with two main engines with jet deflection adjustable to 45°, and two auxiliary engines with jets deflectable between 45 and 60° plus jet control nozzles for pitch and roll stabilization.

In order to find the optimum relationship between vertical and horizontal components of thrust, more exhaustive research is needed, in which the practical side, in particular controllability at very low take-off speeds, cannot be neglected.

In the elaboration of its STOL aircraft projects, the Divisione Aviazione of the Fiat Works has been guided by this parametric method in investigations into the influence of propulsion systems on weight and take-off performance. We chose the G.91, which has been tested, as our point of departure and carried out our investigation by stages, in which each successive step was of a somewhat more radical nature than the preceding one. In this way the difficulties can be methodically overcome, and the drawbacks and advantages of each individual stage of solution can be accurately established.

From the start of the G.95 project, which conforms to more stringent tactical requirements, we have attempted to stay as close as possible to the proven general layout of the G.91. Hence, we selected the same wing loading, but considerably increased the thrust-to-weight ratio. Further, we decided on a composite propulsion system, in which the take-off weight could be kept in the vicinity of the parametrically ascertained optimum value (see *Fig. 1*). In spite of radically improved take-off performance this type retains unchanged the manoeuvrability of its predecessor.

Thanks to good aerodynamic design giving a maximum lift coefficient of more than 1.5, as well as the incorporation of a major vertical component of thrust for assistance at take-off, it is possible to make the take-off speed roughly equal to the minimum control speed, i.e. to bring it to a value, which enables the aircraft to be steered by its aerodynamic control surfaces alone. The take-off distance to the height of 50 ft will then amount to about 1,200 ft.

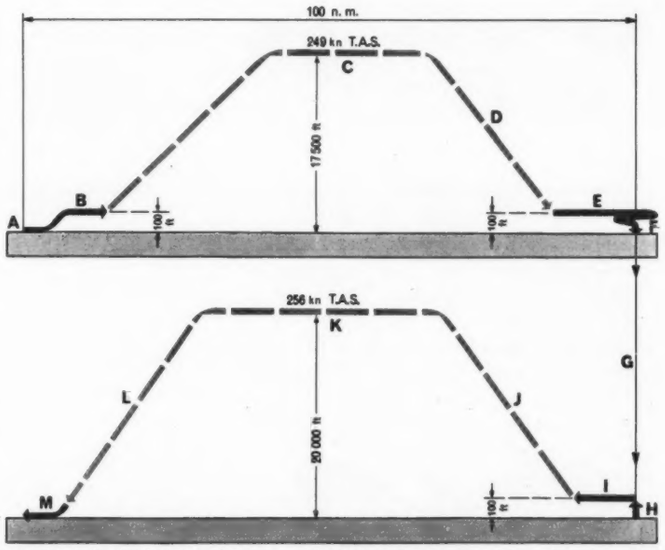
As a further step to improved take-off performance, the installation of a rather complex system of jet deflection has been provided for. This system will deliver a greater vertical thrust component, but will at the same time make necessary a jet control system, since the take-off speed must sink considerably below the value of the minimum control speed. The compensation for this unavoidable complication is that we can now shorten the take-off distance to 850 ft.

By carrying this idea further, the formula will eventually yield a pure VTOL aircraft; nevertheless all the special problems which are tied up with the VTOL concept will have to be solved before then.

The Divisione Aviazione has gone ahead cautiously with the Fiat G.95 STOL aircraft project; we chose a concept which would not be too difficult to realize and which would take into account the most modern requirements for a strike aircraft but would not exclude further development based on experience and knowledge which is lacking at the present time. *Fig. 3* shows a comparison of the take-off performance of the G.91 with those of the two stages of the G.95; *Fig. 4* is a drawing of the second development phase of the G.95, which is to be provided with two main powerplants incorporating a device for deflecting the jet stream and two auxiliary powerplants for take-off as well as a jet control system. ←

What Will Tomorrow's Tactical Transport Look Like?

At a time when high-ranking Western military personalities are slowly getting ready to establish definite specifications for transports, this question may seem premature. But it is undeniable that certain basic specifications will be in agreement in all manuals of requirements—with obvious differences in detail. The point of departure for the new formula is independence from prepared airfields, which offer an enemy an easy target and which in wartime would draw the first attacks. The accuracy of aim, destructive power, and surprise factor inherent in modern guided weapons lead to a defence concept whose essentials have been frequently and exhaustively discussed in *Interavia*. Within the framework of this concept, a decisive role will be given to the tactical transport: it must supply the widely dispersed ground troops and air forces within the battle zone.



A typical mission for a battle zone transport. The figures relate to a project for a V/STOL version of the Short PD.16 which was begun more than five years ago and must be considered obsolete today. Nevertheless, the following flight plan for a transport mission into the battle zone is typical—the aircraft starts with full payload from the supply base (A) where a temporary runway is available, takes off—boosted by lift jets—after a short run, then climbs to about 100 feet where it is accelerated to a safe speed in wing-borne flight (B), and finally climbs to an optimum cruising altitude (C) after the lift jets are closed down. After a conventional descending flight (D) the pilot makes his transition to hovering over the destination (E) and lands the aircraft vertically (F). The return flight reverses this sequence of events: after the payload is unloaded (G) there follows a vertical take-off (H), transition to wing-supported flight, (I) ascent (J), cruising flight (K) now at a higher altitude because of the reduction of weight, descent (L) and finally landing, with the aid of the lift jets (M). Unbroken lines denote phases of the flight where the lift jets are in operation.

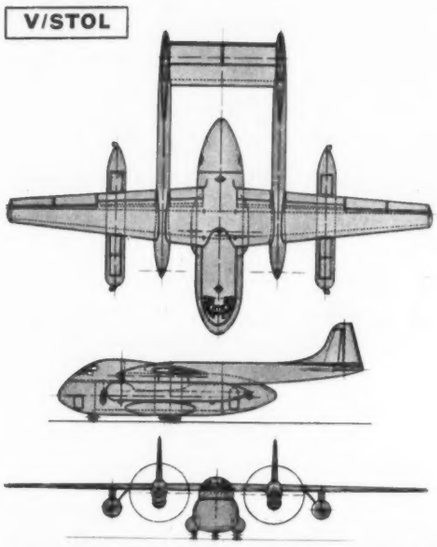
To fulfil completely the missions entrusted to it, a VTOL or STOL strike aircraft must have a supply system behind it which can provide its fuel, spares, ground equipment and weapons, a system which is as mobile as the strike aircraft itself. Otherwise there is no advantage to be derived from its take-off and landing characteristics. This means that supply by other means than by air is out of the question. In other words, the battle zone transport must get along with modest temporary airfields, just as the coming generation of combat aircraft must do. If it is to function at reasonable cost, be able to take-off vertically, or at least make a steep initial climb, robust construction, excluding complex and hence vulnerable equipment, is essential. Finally, a certain flexibility is necessary, to guarantee low flying ability over hilly country and to permit penetration under enemy radar defences. VTOLs and STOLs are best suited for use under these conditions.

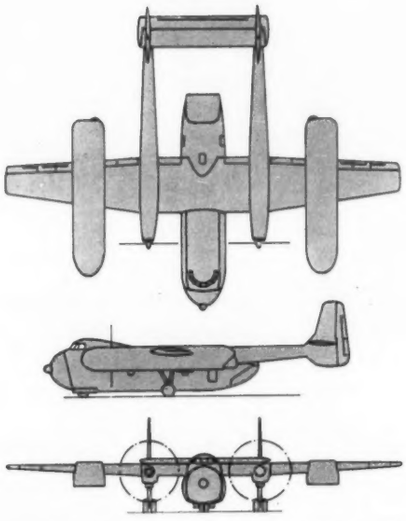
So far, so good. All military planners are agreed on these general lines, although there are differences of opinion as to the degree of short take-off ability required. Is the vertical take-off idea to be entirely rejected? Can design requirements be satisfied by short take-off distances?

All these limitations reduce the designer's freedom to plan, yet they do not necessarily determine the main lines of the aircraft. The decisive factor in the design of transport must always be cargo-carrying performance, expressed in ton-miles per hour, in other terms the product of payload and block speed. Even for a given product, there is a further determining factor. There is a lower limit to payload, which must take account of the weights of indivisible units such as weapons or vehicles. For the tactical transport, this lower limit must lie in the neighbourhood of four tons. It is clear that with VTOL and STOL aircraft, the old rule of decreasing range with increasing payload still applies. For European purposes, 300 miles at full payload must be taken as the shortest possible range. Speed require-

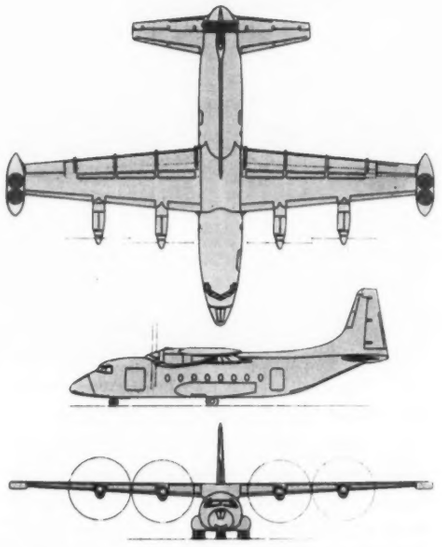
Two American helicopter manufacturers, Hiller and Vertol, have subscribed to the swivel-wing principle. Here, the Hiller X-18, conceived as an experimental model and provided with two Allison YT40 turboprops with counter-rotating propellers (each developing 5,535 h.p.) is seen in three typical configurations. The huge jet nozzle at the fuselage rear, supplied by a special jet engine of 3,400 lb thrust, is clearly recognizable.

V/STOL

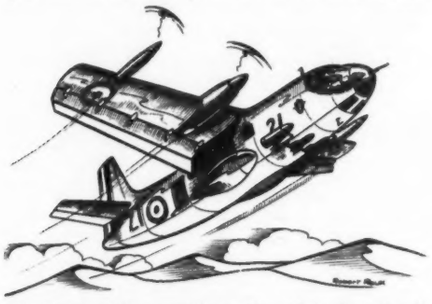




These two British designs for a V/STOL transport are surprisingly similar. The design at the left originated at Short Brothers & Harland and goes back to a 1955 proposal for a VTOL version of the PD.16 cargo aircraft. For lift in hovering flight, 36 lifting jets (Rolls-Royce RB.108s) are used in two pods under the wings, while propulsion in forward flight is by two Bristol *Proteus 755* propeller turbines. The stabilization nozzles can be seen at the ends of the engine pods which are laid out along the same lines as in the Short SC.1. The design at the right is a project which has only become public knowledge in recent months—a V/STOL version from Armstrong-Whitworth for the *Argosy*. Instead of external engines, two pods with 10 lift jets each (Rolls-Royce RB.162) are employed; in addition, turboprops of higher performance have been provided for forward propulsion.

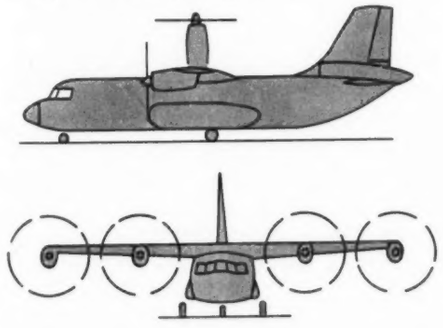


Design by A. V. Roe (Hawker Siddeley Group) for a STOL transport with high lift flaps and vertically operating auxiliary fans at the wingtips.



The Breguet 945, a smaller version of the Breguet 941, and hence called the "Bébé 941," with a total weight of about 10 tons, can carry a payload of 3,300 lb for a distance of 900 miles. The powerplant will consist of two 1,250 h.p. Turboméca *Turmo III D* engines, driving the four propellers, and allowing the Breguet 945 to cruise at a speed of 240 m.p.h. At maximum take-off weight, the aircraft can take off in the tropics or from high altitude airfields, in less than 1,000 ft of runway.

British proposal for a V/STOL transport with a swivelling wing (Hawker-Siddeley group).



ments vary between 220 and 300 knots, hence they cover the speed range where the propeller—free or ducted—appears to be the most economical means of propulsion. In fact, most designs or suggestions for V/STOL transports announced hitherto have been propeller-driven, largely by turboprops, which are now being replaced—thanks to the amazingly rapid appearance of by-pass engines—as powerplants for any sort of air transport which demands speed. This does not alter the fact that the turboprop still retains an area of application for civil and military cargo aircraft.

In looking at designs for S/VTOL transports, or glancing over proposals or ideas which could lead to such designs, it is very evident that "national" differences exist among them, far more striking differences than appear in projects for VTOL combat aircraft. In England the Short SC.1 has impressively proven the feasibility of the principle enshrined in the slogan "lift jets for hovering and independent jet engines for propulsion." By giving conventional transports two batteries of ultra-light lift jets they can be transformed into VTOL aircraft. Furthermore, it must be remembered that Short in 1955 had already offered a thoroughly modern-looking VTOL version of its then current cargo design, the PD.16. The similarity of the Hawker Siddeley Group's new *Argosy* VTOL project to the Short design is quite unmistakable. Recent reports have it that the RAF is taking a lively interest in this new version; final specifications may be expected before the end of the year. It doubtless consists of a conventional supply transport of high cargo capacity with full VTOL characteristics created by the addition of lifting engines resulting in a slight sacrifice of payload or range. All the same, the principle of separate engines for

Technical data Breguet 941 M

Measurements

Wing span	76.1 ft
Length	74.4 ft
Wing area	887.6 sq.ft.
Length of cargo hold	35.7 ft
Width of hold	8.0 ft
Height of hold	7.3 ft
Useful area of hold	285 sq.ft.
Maximum loading of hold floor	153.6 lb/sq. ft.
Useful volume of hold	2,118.87 cu. ft.

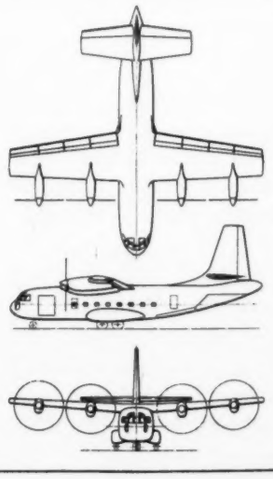
Weights

Normal take-off weight, combat purposes	39,700 lb
Maximum take-off weight	44,000 lb
Maximum landing weight	39,683 lb
Maximum payload	13,200 lb

Performance

Powerplant: 4 turbojets of 1,250 h.p. each (Turbomeca *Turmo III D* or General Electric T58 or DH Gnome)	
Propellers: Ratier-Figeac, diameter	14.7 ft
Cruising speed altitude of 10,000 ft	250 m.p.h.
Range with useful load of 6 tons	434 m.p.h.
Range with useful load of 3 tons	1,180 miles

The following are valid at sea level and normal atmospheric density:		Take-off weight 39,700 lb	Take-off weight 44,000 lb
Take-off roll	concrete	443 ft	623 ft
	grass	492 ft	721 ft
Take-off distance to height of 35 ft without engine failure			
	concrete	770 ft	1,017 ft
	grass	820 ft	1,115 ft
Take-off distance to height of 35 ft with engine failure	concrete	935 ft	1,312 ft
	grass	984 ft	1,443 ft
		Landing weight 35,200 lb	Landing weight 39,700 lb
Landing roll	concrete	311 ft	393 ft
	grass	393 ft	475 ft
Landing distance from height of 50 ft			
	concrete	705 ft	802 ft
	grass	787 ft	902 ft



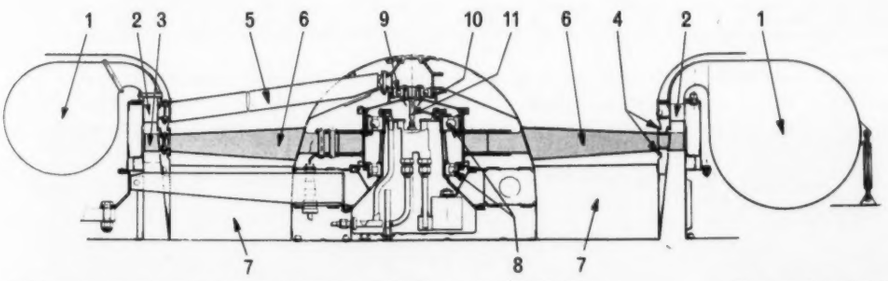
In co-operation with Pratt and Whitney, Chance Vought has developed a new propulsive system called ADAM (Air Deflection and Modulation) for VTOL and STOL aircraft. Four fans produce a slipstream which can be controlled by vanes to produce lift for hovering flight and also to stabilize the aircraft. The fans are driven by turbines impelled by the combustion gases from the four Pratt & Whitney J60 engines mounted above the wings. Crossflow connections maintain stability in the case of an engine failure. In addition to the model of a supply transport shown here, Chance Vought plans a battle zone transport with clamshell loading doors and built-in loading ramp, twin tail booms, and a finless elevator unit. The speed is to be approximately 400 knots.

On September 26th, 1960 Piasecki Aircraft received a U.S. patent for this V/STOL aircraft with its "integrated" system for lift and forward thrust. Typical of this system is a combination of ducted propeller, ring-shaped wing and slipstream deflecting unit. The powerplant for the variable pitch propellers is situated within the fuselage, and in addition there is a stabilizing jet nozzle at the rear. The ring-shaped wing, which is cut away in a curve below, permits the slipstream to be deflected just behind the propellers. This is achieved with a system of semi-independent flaps. In the lower section the flaps form a grille with diverging channels, which work as diffusors and so increase the thrust. The topmost flap is built into the rear edge of the ring-shaped wing and serves as a landing flap and aileron. Wind tunnel tests carried out with scale models under contract to the U.S. Navy Bureau of Aeronautics have been most encouraging.

lift and thrust has first to pass the test of "enlarged scale," for 20 (or 36) lift jets create more problems than the four simple jets of the SC.1. Last but not least, the high-speed jet blasts make a certain minimum preparation of take-off and landing sites essential, which is difficult to reconcile with total mobility.

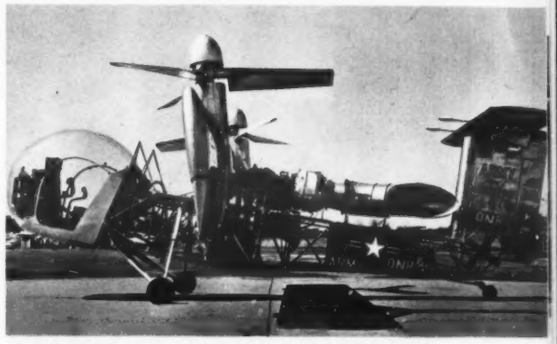
In France a successful trial model, the Breguet 941, derived from its prototype, the Breguet 940, is approaching completion, and will be flight tested this coming spring. Fitted with Messier *Jockey* landing gear and low pressure tyres, the Breguet takes off at normal weight from grass strips of 1,000 foot length, and needs less than 800 ft for landing. These figures are considerably lessened with reduced landing and take-off weights. Four Turbomeca *Turmo IIIDs* of 1,250 hp. each are being considered for powerplants; at cruising speed these will consume 0.59 pounds of fuel per horsepower per hour, and by 1963 the interval between overhauls will be 1,500 hours. Further technical data will be found in the adjoining box. For this model, Breguet expects extremely good sales. It is also to be offered in a civil version, with a fuselage of circular cross-section and a pressurized cabin.

While European designers are adhering to the classical aircraft configuration—apart from the Hawker Siddeley Group's swivelling wing project—their U.S. colleagues are striking out along new and no less promising paths. The prospects of the swivel wing principle, advocated by Hiller and the Boeing Vertol Division, cannot be evaluated at present. Yet the Hiller X-18 can carry the respectable weight of 15 tons, powered by its four counter-rotating lift and thrust propellers; this makes it the most successful weight carrier of all VTOLs now in operation. After the German NSU rotary piston engine (also known as the Wankel engine after its inventor) undergoes the further development which is justified by its light weight and low fuel consumption, Curtiss-Wright intends to use it in competition with the small gas turbine; pictures of the model of the X-200 show an application of the rotary piston engine as a swivelling powerplant with a propeller for both lift and forward propulsion.



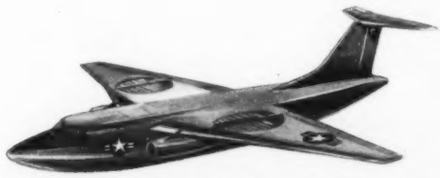
Section through the TLF-2 turbo lifting fan made by Orenda Engines Ltd., Toronto, which has been derived from the jet lift assembly of the *Avrocar* experimental VTOL aircraft. Drive is provided, as in the General Electric turbo lifting fan, by a coaxial gas turbine acting on the periphery. Main data: total thrust (turbine jet and fan jet) 3,000 lb; speed 5,250 r.p.m.; air flow 164 lb/sec; fan compression ratio 1.15 : 1; gas flow 23 lb/sec; turbine intake temperature 630°C; turbine intake pressure 30.43 psi; total weight 250 lb.

1. spiral intake;
2. turbine rim;
3. turbine blades;
4. gaskets;
5. supporting arm for hub cover;
6. blades (31 in all);
7. supplementary guide blades for torque reduction, which at the same time support the hub;
8. main bearing (ball bearings take up radial and axial forces, roller bearings take up radial forces only);
9. supplementary bearings;
10. gasket;
11. oil pump drive.



The Vertol 76, powered by a Lycoming T53 turbojet, designed and built by Vertol under contract to the Office of Naval Research, and now undergoing tests at the U.S. National Aeronautics and Space Administration.

Piasecki's ring wing is one of the most original solutions to the problem, and the Chance-Vought ADAM (Air Deflection and Modulation) aircraft, now only a model, is equally radical in its design. The latter employs the airstream from a gas turbine-driven fan set parallel to the main engine to create lift and stabilization, with deflector plates to provide forward propulsion. In contrast there is the General Electric project followed recently by Orenda, whose lift fans are



Design for a four-ton payload battle zone transport, equipped with two General Electric lift fans.

housed horizontally within the aircraft and serve merely for hovering and transitional flight. The main difference between these projects lies in the fact that Orenda's design has the turbine drive mounted in the rim of the lift fan and for this reason can be contained in shallow dimensions.

As this article goes to press, a U.S. Navy announcement should have appeared about a V/STOL combat transport for all three services. The development costs will amount to 70 or 80 million dollars spaced out over the next four years. According to reports, a payload of four tons, a range of 1,500 miles and a speed of 300 knots is required. It is doubtful, however, whether all three services will agree on a single type. The substantial production programme to follow upon the development order will attract a number of constructors to this programme, even those who have not submitted designs so far.

It should be stressed that this informal review—coming as it does in the midst of a spate of development—can make no claim to completeness. Nevertheless, the variety in the few examples discussed here demonstrates that designers cannot be accused of lacking imagination. The clients will be hard pressed to make the proper choice, and their decision will be complicated even more by tactical and technical considerations, which in company with economic and political factors will play a decisive role. ←→

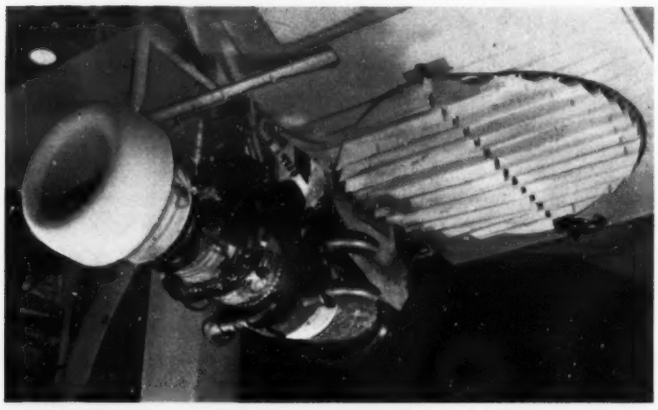
V/STOL

General Electric Lift Fans

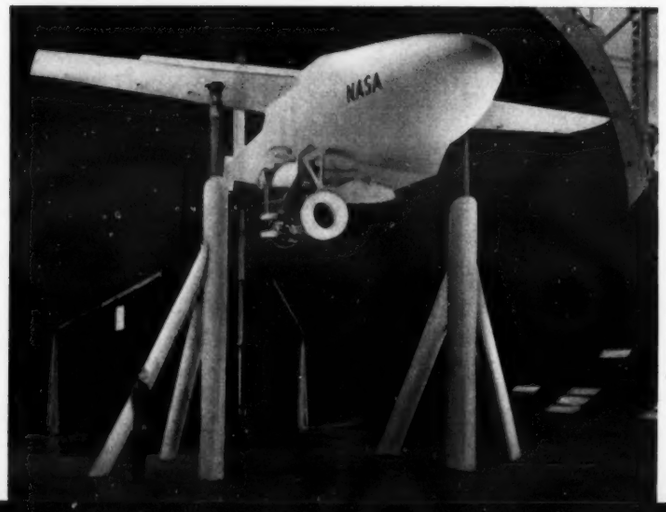
Diagram of a General Electric Company lift unit. A – gas generator, which works like a normal jet engine in forward flight; B – diverter valve, which leads the exhaust gases either to the jet pipe or to the tip turbine; C – jet pipe; D – tip turbine; E – lift fan.

From its earliest beginnings, the development of aircraft design has been largely determined by progress in engine building. This statement is not in any way intended to belittle the achievements of aerodynamicists and stress analysts, equipment designers and electronics engineers, without whose skill we should still be flying wire and canvas contraptions. But there is no denying the fact that nearly every aircraft design is based on an engine either already available or undergoing development, and it is around the engine that the airframe is more or less built.

In the case of the normal take-off aircraft, interest is confined to engine thrust parallel to the fuselage axis, whether this be generated by a propeller or the efflux of a jet engine; on the other hand, vertical take-off, and to a limited extent short take-off, require a substantial thrust force perpendicular to the aircraft's longitudinal axis (apart from the case of the tail-sitter configuration, now evidently abandoned). Newton's Law states that force equals mass multiplied by acceleration. In other words, any heavier-than-air craft must accelerate a certain mass downwards to generate lift, a mass which, apart from the case of rocket propulsion, is taken from the surrounding air. In the conventional aircraft, lift is generated with the aid of the wing; for the purpose of slow hovering flight, however, the wing produces inadequate lift or no lift at all.



This full-size mockup of a military VTOL reconnaissance aircraft, fitted with a General Electric X-353-5 lift fan, was wind tunnel-tested to determine its stability during transition from hovering to wing-supported flight and *vice versa*. The arrangement of the gas generator—a General Electric J85-3—would possibly differ in an actual aircraft. The results were so satisfactory that General Electric obtained a contract for continued development. Above, a detail picture showing the gas generator and fan louvres on the underside of the fuselage.



In creating VTOL aircraft for subsonic and moderate supersonic speeds, the designer is faced with a dilemma: the thrust available for jet lift must be greater than the aircraft weight, while far less thrust is needed to power the aircraft during cruise. An engine whose thrust is used directly to produce lift for vertical take-off and later for forward propulsion in wing-borne flight, would in many cases be too powerful for the latter and hence uneconomic—no matter how thrust vector control were achieved. In Britain, this consideration has led to the development of extra light lift jets which run for only a short time and can therefore be developed for a short life and a relatively high fuel consumption. This, however, demands not only the time-consuming and costly development of new engines, but also increases the costs of maintenance and spares.

It was these reasons that led General Electric's engineers to seek new solutions which avoided the disadvantages set out above. After exhaustive studies of different types of VTOL powerplant, they decided on a combination of conventional turbojet and lift fan, in which the efflux from the former is used to drive a tip turbine around the rim of the latter. In forward flight the turbine works "normally," i.e., like an ordinary propeller turbine or jet.

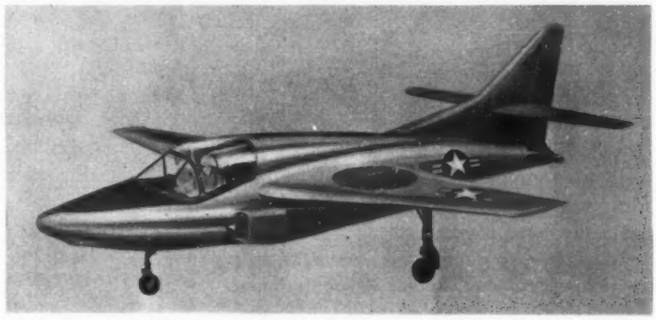
Once the basic principle had been established, it was necessary to investigate its suitability for the most difficult flight phase of any VTOL aircraft, namely transition from jet-supported hovering flight to wing-supported forward flight. The U.S. Army showed a lively interest in this formula and financed the construction of a full size mockup of a two-seat observation aircraft, which was then tested in the large wind tunnel (test section 40 × 80 ft) at NASA's Ames Research Center. The mockup was fitted with a wing designed for high subsonic speeds, with slotted flaps over the whole span, to provide lift at a forward speed of about 100 knots. A jet nozzle at the mockup tail provided additional longitudinal trim, and the J85 light jet engine served as gas generator. In an extensive series of tests various combinations of determining factors were investigated: lift fan rate of rotation, flight speed, pitch of the louvres under the fan outlet, angle of attack of wings and horizontal tailplane, angle of wing flaps. A number of simulated transition flights made under various conditions showed that the system had a gratifyingly high degree of stability. As the angle of attack of the wing increases and the pitch of the louvres is reduced, the lifting

moment decreases, thus contributing to attitude stabilization. On the other hand, the lifting moment increases with flight speed, providing another stabilizing factor. Recycling of exhaust gases was hardly perceptible, even during hovering flight—the temperature of the air passing through the engines rose by less than 20°F—and was completely absent at low forward speeds. Nor were there any dangerous vibrations in the fan, such as those normally caused by asymmetrical flow reaching the turbine.

In the test model, the fan was fitted in the fuselage, so that a relatively long intake duct was available. If the fan is in the wing, the intake duct must of necessity be very short.

The trial unit delivers a lift thrust of 7,430 lb at a specific fuel consumption of 0.34 lb/lb/h, and weighs 1,145 lb, including engine, J85 gas generator, diverter valve, gas duct and fan. The thrust-to-weight ratio of 6.5 may seem modest by comparison with those of the British lift engines (Rolls-Royce 16 : 1, Bristol Siddeley 14 : 1), but it should be remembered that this is the first experimental type in which the primary aim is to test the validity of a concept. General Electric already has under development light gas generators which will ultimately enable a fan thrust-to-weight ratio of about 15 : 1 to be achieved. The company stresses that the main advantage of the system lies less in the thrust-to-weight ratio than in the practically unlimited possibilities for combining forward propulsion engines and lift fans without the necessity for the time-consuming and costly development of separate lift engines. General Electric is at present investigating the suitability of the T58 and T64 propeller turbines and the J79 turbojet as gas generators. It should be noted in passing that there is no reason why use should not be made of a turbofan engine or an afterburner (behind the diverter valve).

In order to generate high thrusts at low efflux velocities, the maximum fan diameter is necessary. On the other hand, the wing chord or fuselage width of a particular aircraft design sets an upper limit, quite apart from the higher weight of larger fans. One possible way of reducing the fan diameter without reducing thrust would be to heat the exhaust gases between the gas generator and the tip turbine by afterburning. But this brings with it the disadvantages of increased fuel consumption and higher fan efflux velocity. The latter is, however, so low that no ground erosion need be feared. What is more, the efflux is cold, for the exhaust of the tip turbine is at once mixed with the fan efflux. In aircraft flying at transonic or high subsonic speeds, the fans must be installed in the fuselage because of the thin wing which is necessary.



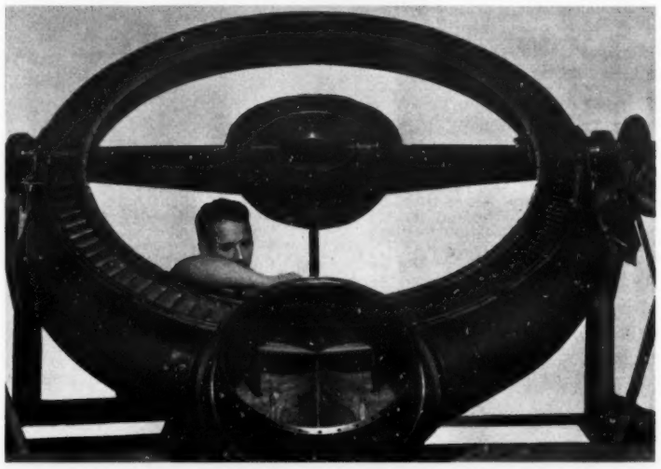
Two General Electric Company proposals for a VTOL observation and short-range reconnaissance aircraft, which could reach speeds of over 350 knots. The design in the lower picture has the engine gas generator units fitted in the fuselage and the lift fans in the wings; in the upper picture the arrangement is reversed. Crossflow connections between the gas ducts and the fan ensure hovering—or at least STOL—capability, even in the event of failure of one engine.

To ensure the safety of the crew, at least two engines must be installed; these can both drive the same fan, or each drive a separate fan. In the latter case, a crossflow connection would, in the event of failure of one engine, distribute the exhaust of the engine which still remained operative equally between the two fans. If a fan or a number of gas generators break down, the pilot's only hope is the quality of his ejection seat.

The take-off of an aircraft fitted with lift fans will proceed roughly as follows: With fan outlet louvres in the vertical position and the diverter valve deflected, the engines, which now work as pure gas generators, are accelerated until the thrust of the fan exceeds the weight of the aircraft and lifts the latter off the ground. After a few yards of vertical climb, the pilot will gradually swivel the fan louvres rearwards, thus generating a horizontal component in the fan thrust. When the forward speed is sufficient for wing-supported flight, the pilot sets the diverter valve for horizontal flow and closes the louvres, which then fit flush with the wing or fuselage skin. The process described is reversed for landing.

*

Development is still only at its beginning, and there is no lack of problems: safety after failure of an engine, automatic stabilization of the aircraft during hovering, the best procedure for transition, reduction of installed weight, reheat between gas generator and fan, and last but not least, the most suitable aircraft configuration. Nevertheless, development so far, which has been financed partially by aircraft builders themselves, holds out the hope that VTOL aircraft designers will soon have yet another attractive propulsive system at their disposal. ←←

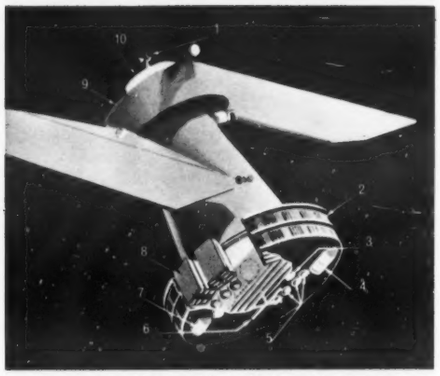


Tip turbine intake and scroll. The deflector plates for dividing the gas flow are visible behind the connector flange. The scroll extends only halfway around the periphery.

The fan being balanced.

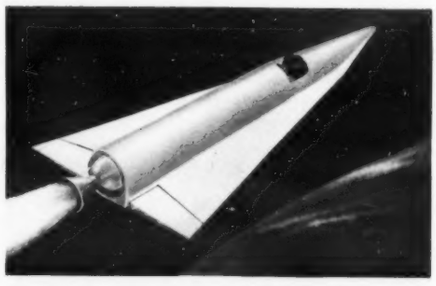
The two positions of the diverter valve. During hovering flight, the engine jet pipe is closed, and the exhaust gases flow through the cowling to the fan tip turbine (left). During wing-supported flight the jet flows straight through the valve (right). Technical data: valve weight 2 lb per lb of gas flow; pressure loss with gas deflection 4 to 6 percent, with direct flow 1.5 to 2 percent; leakage approx. 1 percent of flow.

Rockets, Missiles and Space Vehicles



The *Nimbus* weather satellite, which weighs 650 lb, is to be launched in the first half of 1962 by *Atlas-Agena B* or *Atlas-Centaur* into a polar orbit about 620 miles high. The picture shows the possible form to be taken by the satellite. 1 – control jets; 2 – thermal control vanes; 3 – electrostatic camera; 4 – infra-red scanner; 5 – TV camera (probably with zoom lens); 6 – antenna; 7 – infra-red scanner; 8 – electronic module assemblies; 9 – control section; 10 – power storage.

Aerojet-General Corporation's Spacecraft Division has received a $1 million USAF contract to develop a space glider which might take the form illustrated in the accompanying picture. The vehicle has a wing leading edge sweep of 70° and at an altitude of 300 miles would reach speeds of Mach 5 and over. Models are to be tested in the wind tunnels of the USAF's Advanced Research and Development Center, Wright-Patterson AFB, at flow speeds of Mach 0.8 to Mach 8.



Model of a *Ranger RA-1* in unfolded state: 1 – zero db antenna; 2 – magnetometer; 3 – ion chamber; 4 – Geiger tube and/or semiconductor detectors; 5 – electrostatic analyzer; 6 – composite micrometeorite detector; 7 – launch/backup battery; 8 – triple coincidence detectors (cosmic ray); 9 – pitch and roll jets; 10 – electrostatic analyzer; 11 – sun sensors; 12 – solar cell panel; 13 – yaw jet; 14 – 18 db antenna; 15 – earth sensor and antenna gear box; 16 – electrostatic analyzer; 17 – Lyman Alpha telescope; 18 – equipment for friction experiments.

Tiros II Weather Satellite

The NASA *Tiros II* weather satellite was launched from Cape Canaveral on November 23rd, 1960. A three-stage *Thor-Delta* booster put it into the most regular orbit of all American satellites yet launched, with a perigee of 406 miles and an apogee of 431 miles; the angle of trajectory is given as 48°, the orbital period as 98 minutes.

The 280 lb satellite is equipped with two television cameras, seven infra-red sensors and instruments to measure solar radiation. The spin stabilization system is working satisfactorily, the spin rate having been reduced from an initial 126 per minute to 13.9. At this rate, which is maintained constant with the aid of small rockets, the cameras can take photographs without blurring. Five transmitters, working on 108 Mc/s, 108.3 Mc/s, 235 Mc/s (two transmitters) and 237.8 Mc/s, transmit pictures and data. The power supply is provided by over 9,000 solar cells and by chemical batteries. The U.S. Army Signal Corps received the first cloud pictures about four hours after *Tiros II* was launched.

The USA has invited 21 nations to participate in the *Tiros II* experiment. Countries which have accepted are Australia, Belgium, Denmark, France, West Germany, Great Britain, India, Japan, Mexico, the Netherlands, Norway, South Africa, Sweden and Switzerland.

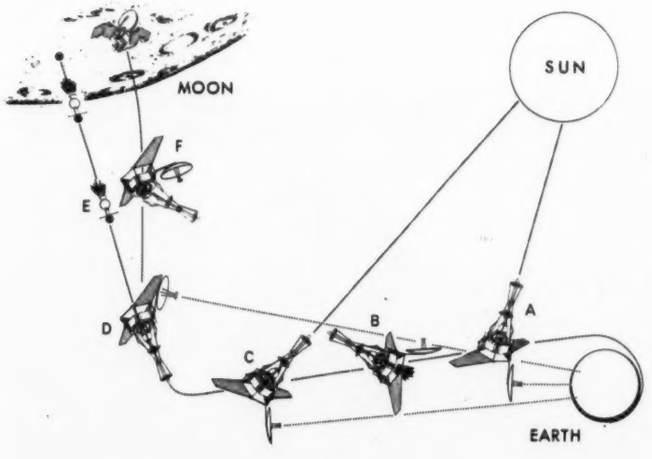
Project Ranger

Among the many proposals for lunar vehicles, NASA's *Ranger* project occupies a special position, as its development is the furthest advanced and first tests are due to be made in 1961/62. Main contractor for the project is the California Institute of Technology's Jet Propulsion Laboratory, while the Aeronutronic Division of Ford Motor Company is responsible for the instrument capsule, Hercules Powder Company for the solid-propellant retro-rocket, and Ryan Aeronautics for the radio altimeter.

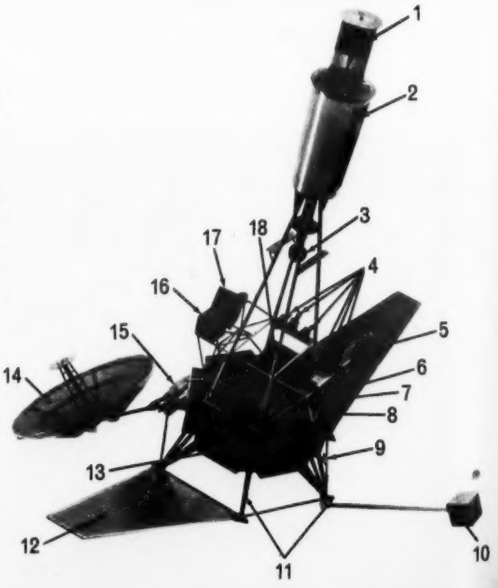
The accompanying table shows the NASA project designations, the vehicle numbers, projected experiments, instruments and the responsible agencies and scientists. According to Clifford I. Cummings, JPL's Spacecraft Program Director, the *Ranger* spacecraft must meet the following requirements: full attitude stabilization by means of control nozzles or gyros, their own propulsion and guidance systems for mid-course and terminal manoeuvres, independent power supply from solar cells or nuclear devices, a store of pre-programmed information for future action, logic circuits to perform particular missions which vary in accordance with conditions, and a communication system utilizing the available power and bandwidth in the optimum fashion. Design work on the *Ranger* is almost completed. The spacecraft will be about 12 ft long and will weigh 700 to 800 lb.

Dr. Eberhardt Rechtin, Head of Communications Projects at JPL, has said that he expects a high degree of efficiency from the antenna, thanks to the attitude control on *Ranger*. The two transmitters will have a power of 0.25 and 3 watts respectively, and will transmit between 1,000 Mc/s and 2,300 Mc/s (frequencies which are little affected by solar flares). According to J.D. Burke, Head of the *Ranger* programme at JPL, the instrument capsule plus solid-propellant retro-rocket and accessories will weigh 100 lb and contain about 40 lb of crushable material to absorb the landing shock on the moon.

Ranger will be launched by means of an *Atlas-Agena B*, with NASA's Marshall Space Flight

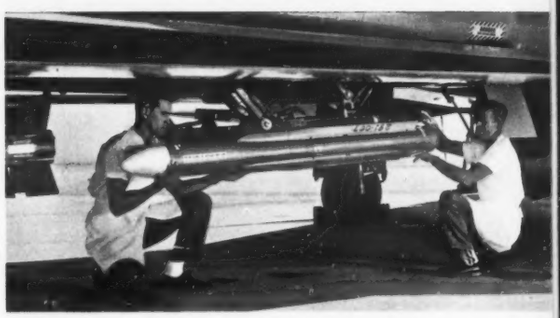


Lunar flight of *Ranger:* The vehicle is stabilized so that its solar cells face towards the sun, its antenna earthwards (A). At (B) the vehicle makes an in-course guidance manoeuvre to put it on a collision course to the moon. At (C) it re-orients itself to the sun and earth. At point (D) the instrument capsule (E) is ejected; it makes a hard landing on the moon, while the vehicle itself (F) is destroyed on impact.



Center being responsible for launching preparations and initial guidance. The actual spacecraft will be guided into the Oceanis Procelarium by a modified ICBM radio command guidance system, and landing should take place within an area of approximately 1,000 sq. miles. Later shots will be programmed to hit a more specific target. Some 66 hours after launching, the craft will automatically position itself in such a way that the television camera can photograph the moon's surface. At roughly 20 miles from the moon, the instrument capsule will separate from the rest of the vehicle and reduce its speed with the aid of the retro-rocket (ignited on a signal from the radio altimeter) from roughly 6,500 m.p.h. to about 200 m.p.h. It is assumed that the 50 lb of instruments and equipments will survive the hard landing. The measurements they provide will be among the first direct data on the earth's natural satellite.

Short Brothers and Harland Ltd. has designed a transport container for the *Seacat* ship-to-air guided missile; this will also protect the weapon from the effects of severe weather. A closely fitting plastic envelope is sealed to a circular metal base to guard against humidity. Over this is fixed a fibreglass container, which is also attached to the circular base. The container is not removed until the missile is on its launcher. When the *Seacat* is fired, the plastic envelope tears at special bursting seams. A double cage of tubular steel, only partially visible in the picture, serves for transport.



Hughes Aircraft Company weapons system evaluator missile (WSEM).

NASA Designation (vehicle)	Experiment	Instruments	Agency and Scientist
P-32 *(Ranger RA-1)*	In high elliptical orbit Engineering tests of attitude control system, solar and battery power supplies, communication equipment, lifetime of components in space environment Scientific studies of interplanetary medium; i.e., fields and charged particles, solar X-rays Hydrogen geocorona Interplanetary dust	1. Electrostatic analyzer for solar plasma 2. Semiconductor detectors and thin-walled Geiger counter a) CdS photoconductor b) Thin-walled Geiger c) Medium-walled Geiger d) Au-Si counter 3. Ionization chamber 4. Triple-coincidence telescopes 5. Rubidium vapour magnetometer 6. X-ray scintillation detectors 7. Lyman Alpha telescope 8. Micrometeorite composite detectors	JPL (M. Neugebauer, C. Snyder) State University of Iowa/ University of Chicago (J. A. van Allen/J. A. Simpson) Caltech/JPL (H. V. Neher/ H. R. Anderson) University of Chicago (J. A. Simpson) Goddard Space Flight Center (J. P. Heppner) LASL/ Sandia Corp. (J. A. Northrop) Naval Research Lab/JPL (T. A. Chubb) Goddard Space Flight Center (W.M. Alexander)
P-33 (RA-2)	Lunar fly-by; otherwise as above	As P-32	As P-32
P-34 (RA-3) P-35 (RA-4) P-36 (RA-5)	Engineering tests of landing survivable package on moon and mid-course guidance technique Scientific studies of lunar environment and surface Capsule: seismology and temperature measurement Vehicle: Gamma ray spectroscopy and photography of small lunar area	1. Seismometer 2. Thermometer 3. Gamma ray spectrometer 4. Vidicon television	Caltech/Columbia University (F. Press/M. Ewing) University of California/LASL/ JPL (J. R. Arnold, M. A. van Dilla/E. C. Anderson/ A. Metzger) JPL (E. F. Dobies)

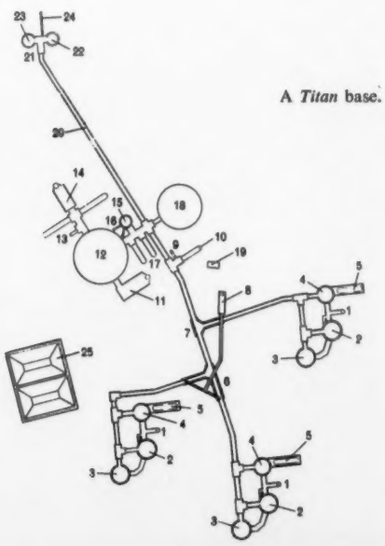
Geophysical satellites

NASA will spend up to $100 million during the next eight years on the development of satellites for geophysical observations; these are to bear the designation OGO (Orbiting Geophysical Observatory). They will weigh about 1,000 lb, at least 150 lb being accounted for by the instrumentation. It must be possible to increase the satellite weight to 1,500 lb, with an instrument payload of up to 500 lb. Little is known regarding the size of the satellites, though a maximum diameter of 56 in. has been proposed; the surface area should be at least 30 sq.ft. Power will be supplied by solar cells and chemical batteries. The instrumentation will serve for about fifty different experiments in the following areas of research: magnetic fields, charged particles, interplanetary dust, structure of the atmosphere, ionosphere, solar physics, astronomy, meteorology, properties of planetary surfaces and environment, technology, biology etc.

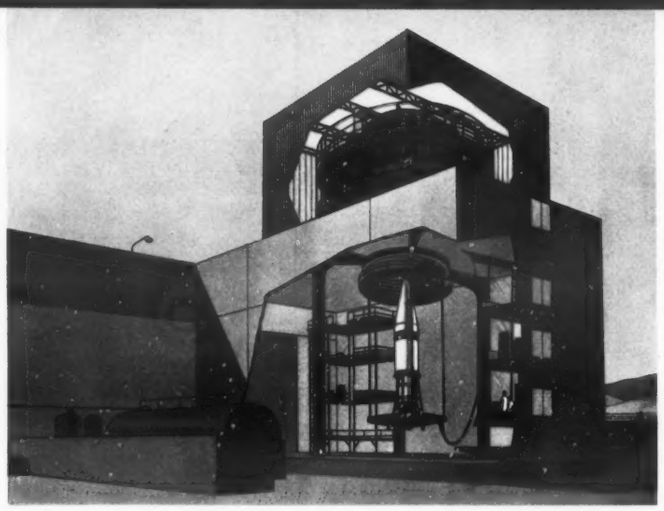
The first launchings will be made under NASA projects S-49 and S-50. Project S-49 is the EGO (Eccentric orbiting Geophysical Observatory) satellite, which will be launched by *Atlas-Agena B* from Cape Canaveral into an orbit with a perigee of 150 n.m. and an apogee of 60,000 n.m.; angle of trajectory 31°. NASA project S-50 is the POGO (Polar Orbiting Geophysical Observatory), which is to be launched by *Thor-Agena B* from Vandenberg AFB into an orbit with a perigee of 150 n.m. and an apogee of 600 n.m.

A *Titan* base under construction at Denver, Colorado. At front and to the right are three launch silos 165 ft deep.

Layout plan of the *Titan* base: 1 – lox fill and vent; 2 – launch silo; 3 – equipment terminal; 4 – propellant terminal; 5 – lox tank; 6 and 7 – blast locks; 8 – launcher area filtration facility; 9 – nitrogen tank; 10 – missile fuel tank; 11 – powerhouse air filtration facility; 12 – powerhouse; 13 – diesel oil tanks; 14 – powerhouse exhaust facility; 15 – main entrance; 16 – TV camera and instrument mounts; 17 – water storage tanks; 18 – control centre; 19 – chemical waste clarifier; 20 – personnel tunnel; 21 – antenna terminal; 22 – antenna No. 1; 23 – antenna No. 2; 24 – exhaust vent; 25 – sewage stabilization pond.



A *Titan* base.



This aerospace chamber to test satellites and space vehicles is under construction for Lockheed Aircraft Corporation's Missiles and Space Division.

Hughes weapons system evaluator missile

A few years ago, when Hughes *Falcon* air-to-air guided missiles failed to reach their prescribed trajectory, Hughes Aircraft Company developed a piece of test equipment to determine whether the fault lay with the missile, the fire control system or the pilot. This equipment, the WSEM (Weapon System Evaluator Missile), has now gone into production. It enables the missile launching to be checked at low cost and serves for training pilots of the USAF Air Defense Command.

The WSEM (see picture) is virtually a "*Falcon* with clipped wings," i.e., carrying a signal recorder in place of the rocket engine and control surface servo positioners. The missile carries no warhead, but is fitted with a complete infra-red or radar homing system. In simulated attacks the WSEM takes the place of the *Falcon;* in actual firings using practice targets it is carried in addition to the live weapons, though not actually launched. Data are recorded on a 15 ft roll of photographic paper. Every action of the pilot, every process in the fire control system, and the behaviour of the WSEM or live *Falcon* during simulated or actual firing, deflects a beam of light directed onto the paper strip. After development of the paper, the trace will show how the pilot, the fire control system and the weapon have operated together. The WSEM can be used with all versions of the *Falcon*.

Lockheed satellite test chamber

In addition to the aerospace chambers at the Rye Canyon Research Center (cf. *Interavia* No. 12/1960, page 1464), Lockheed is building a further test chamber (see picture) at Sunnyvale, California, to simulate conditions in space. Known as HIVOS (High Vacuum Orbital Simulator), the new facility will serve mainly for testing the *Agena,* but can also be used for other satellites and space vehicles.

A vacuum pump system will keep the chamber at a pressure corresponding to an altitude of about 200 miles. Panels of quartz lamps close to the surface of the space vehicle will generate a maximum heat of 1,000 BTU/sq.ft./h. The chamber can be cooled down to temperatures of —320°F by liquid nitrogen.

Housed in a 90 ft high building, the chamber will have an internal diameter of 18 ft and a height of 20 ft, which can be increased to 35 ft if desired. As the floor of the test chamber will be 47 ft above ground level, the satellites and spacecraft to be tested can be loaded in from below.

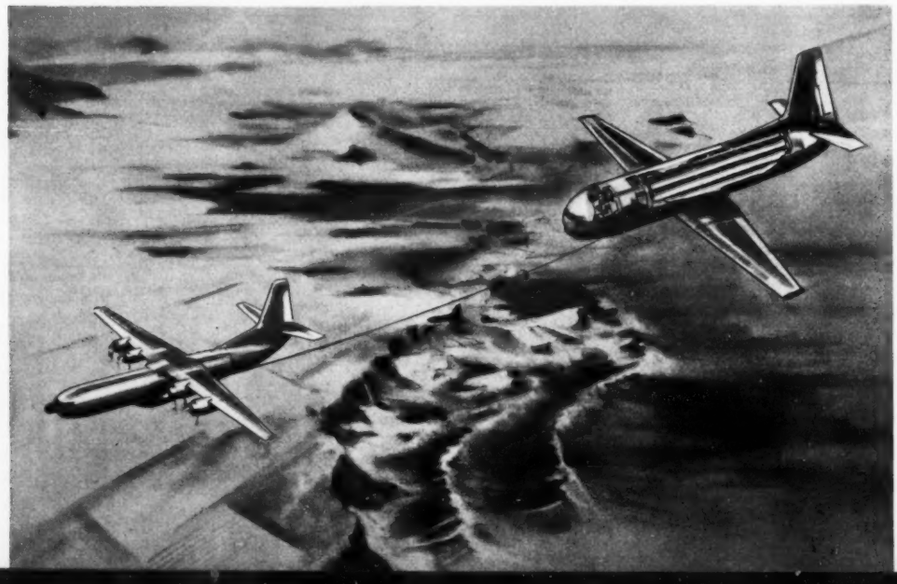
Consolidated Vacuum Corporation, of Rochester, New York, has received the contract for the facility, which will cost about $1.6 million to build. The complete installation, which should be ready by August, 1961, will cost $3.5 million.

Gliders for rocket booster transport

Lockheed Missiles and Space Division has proposed giant gliders to transport large rocket stages such as the multi-engine *Saturn;* these could be towed by aircraft of the Douglas C-133 class. Neither railways nor the highway networks allow the transport of the assembled rockets, so that the most acceptable solution to this problem is transport by barge. At present, time in transit by water ranges from five to twenty days; a glider could accomplish this in a few hours.

Lockheed has published the following data on a typical towed-glider transport system: wing span 211 ft; gross weight 153,000 lb; payload capacity 110,000 lb; interior length (payload) 96 ft; interior diameter (payload) 24 ft; cruise range 1,200 n.m. (no refuelling); cruise speed 190 knots; take-off distance to clear 50 ft screen 10,000 ft; landing distance 7,000 ft.

Lockheed design for a glider to transport large rocket stages.



Space capsule recovery device

The U.S. Air Force has succeeded in recovering a 500 lb instrument capsule which had been

Goodyear "ballute" recovery device. Above, experimental version of the balloon, diameter 9 ft. When inflated, it brakes re-entry vehicles during free fall (below); in the lower layers of the atmosphere a parachute is used.

carried to a height of 32 miles by rocket (probably a modified Cook Research Laboratories *Cree*). The launching took place at Santa Rosa Island, Florida. The recovery device was a combination of drag balloon and parachute, known as "ballute," developed by Goodyear Aircraft Corporation under contract to the Wright Air Development Division of ARDC. The ballute decelerates nose cones and instrument capsules on their re-entry into the earth's atmosphere. The plastic balloon can be inflated in a tenth of a second and is then held by a cable at a distance from the recovery vehicle at which maximum drag is generated. The normal *Cree* is a solid-propellant rocket with a launch weight of 1,150 lb, and reaches maximum speeds of around 3,000 m.p.h. ←←

Pilot Reports on the X-15

The following report was prepared by the two pilots who have shared the task of carrying out the initial flight trials in the joint Air Force-NASA research program. Major R. M. White, Assistant Chief of Operations Division, Air Force Flight Test Center, Edwards AFB, deals with the maximum altitude flights which he has carried out in the X-15 aircraft. J. A. Walker, Chief Research Pilot, NASA Flight Research Center, reports on the buildup program which culminated in the maximum speed flight, in which a Mach number of 3.31 was achieved. The combined report was presented to the annual symposium of the Society of Experimental Test Pilots, held in Los Angeles on October 7th, 1960. *Editors.*

• Major R. M. White, USAF

The number one X-15 aircraft was delivered by North American Aviation to the joint NASA-Air Force-Navy test force on February 3rd, 1960. Both Joe Walker and I could elaborate at great length on many phases of the program, particularly the development of the aircraft and the tremendous effort expended by many members of government and industry. To limit our scope we will cover quite briefly the preparation for and accomplishment of preliminary flights of the program, the actual maximum speed and maximum altitude flights which we have flown, and some engineering results obtained thus far, and will take a quick look at where we go from here.

The aircraft that we have been flying is equipped with two interim XLR-11 rocket engines developing approximately 16,000 pounds of thrust at altitude. The final XLR-99 engine is now installed in the number two aircraft and will make its initial flight very shortly. Neither the reaction control system nor the q-ball (hot nose) have been used on the flights with the XLR-11 engines. The inertial platform is undergoing checkout and has been operating on these flights; however, it is not yet being used as a primary flight instrument.

None of these systems is required to operate the X-15 within the XLR-11 performance envelope shown in *figure 1*, although at the maximum Mach number, near 3.5, we are certainly reaching the temperature limits of the standard nose boom, and at the maximum altitude, near 135,000 feet, we are operating at the minimum dynamic pressure limits of the pressure instruments. The inner area of *fig. 1* represents the region we have flown into thus far: a maximum altitude of 136,500 feet and a maximum Mach number of 3.31. Also shown is the predicted performance envelope with the XLR-99 engine installation: a maximum Mach number of approximately 6.4 and a design altitude of approximately 250,000 feet.

Program preparation

For many months prior to delivery of the aircraft, the joint test force had been preparing for a minimum flight program to expand the flight envelope with the XLR-11 engines. Our effort was devoted to three main tasks:

(1) The prelaunch period covering the ground support requirements, mating with the B-52, servicing, the preflight check list, and other operational items

(2) The actual powered flights of the X-15

(3) The recovery of the vehicle, including range requirements, emergency operation and recovery, and actual landings.

Since the first item, the prelaunch and support requirements, was fairly well established by North American on their demonstration flights, little needs to be said regarding our effort in this connection.

The second item, that of actual powered flights, was our primary effort. Maximum use was made of analog and digital computers to predict the flight envelope for the aircraft. The analog simulator at North American was then used to determine the piloting techniques required to reach the maximum Mach number and maximum altitude. Once the actual maximum speed and altitude missions were defined, it was necessary to determine what interim data, primarily stability and aircraft control, were required, to assure ourselves that these flights could be made safely.

For the third task, that of recovery of the vehicle, the analog simulator was again used to define the range requirements for each of the flights and for all the conceivable emergencies. This information was used to determine the launch area and the required emergency lakes between the launch point and Rogers Dry Lake, the area of intended recovery.

The F-104A aircraft has proved to be another valuable training aid in the program. By extending the speed brakes and reducing the throttle to idle, we can simulate quite closely the approach configuration of the X-15. As indicated in *figure 2*, the lift-drag ratio (L/D) of both airplanes is then approximately 3.1 at 300 knots, which produces a trimmed rate of descent of approximately 180 feet per second, or over 10,000 feet per minute. The flaps and gear are extended after the flare on the X-15, and this is simulated with the F-104 by extending the take-off flaps and landing gear, producing an L/D as shown on the lower curve.

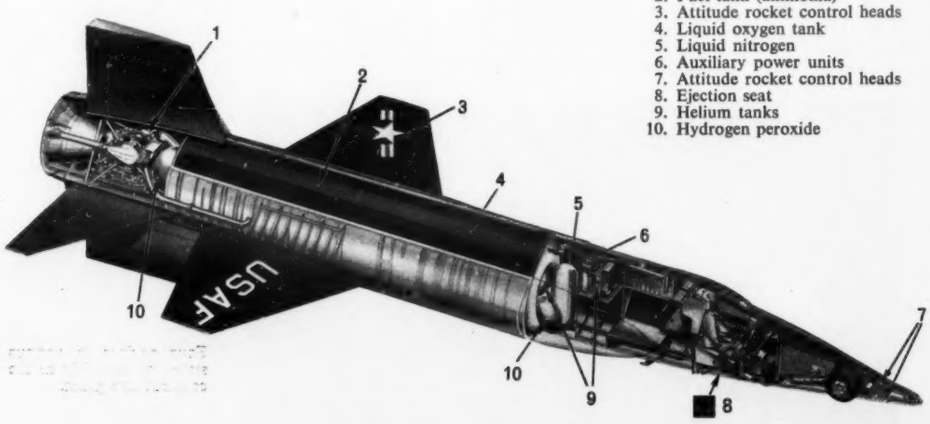
Use of the F-104 allows us to practice landing approaches on Rogers Dry Lake and also on each of the emergency lakes immediately before each flight. The value of this tool is demonstrated by the fact that, although we have each flown the X-15 only four or five times in the last six months, we have been able to land consistently within a maximum of one-half mile of our intended touchdown spot.

Expansion of the flight envelope - altitude

All of this preparation resulted in an eight-flight test program, with Joe Walker and myself flying alternate flights to attain the maximum speed and altitude of the X-15 with the interim engines. Our first flight was completed successfully on March 25th, 1960. Eight flights later, we had attained the maximum speed and altitude almost exactly as planned.

My four flights of this eight-flight program included two local flights in a triangular pattern around Rogers Dry Lake to a maximum Mach number of slightly over 2.0. The third flight was an altitude-buildup flight to approximately 107,000 feet and 2.5 Mach number. This necessarily had to be a flight profile without turns; consequently the X-15 was launched 15 miles east of Silver Lake near Baker, Calif., and flown on a straight track 105 miles back to Rogers Dry Lake. The purpose of this flight was to evaluate

Sectioned view of the X-15 aircraft



1. Thiokol *Pioneer* XLR-99 engine
2. Fuel tank (ammonia)
3. Attitude rocket control heads
4. Liquid oxygen tank
5. Liquid nitrogen
6. Auxiliary power units
7. Attitude rocket control heads
8. Ejection seat
9. Helium tanks
10. Hydrogen peroxide

the climb and pull-up techniques which would be used on the maximum-altitude flight, and to obtain stability data which would assure us that the mission could be flown safely.

The maximum-altitude flight was made on August 12th, 1960. With the aid of *figure 3*, I can run through the sequence of flight events to explain the piloting technique on the flight. After launch from the B-52 at 45,000 feet, I lit all eight thrust chambers while monitoring an 8° angle of attack. With the application of thrust, the initial altitude loss was arrested at about 39,000 feet and the climb maintained to 60,000 feet. At this altitude I accelerated to 1.9 Mach number, then started a 1.5 g pull-up and maintained this g-level until attaining full-back stick at 18.5° angle of attack. Full aft longitudinal control corresponds to 35° of stabilizer deflection, and the aircraft pitch angle at this point was 48.5°. Engine burnout occurred at 118,000 feet and the angle of attack was reduced to 10°.

A large discrepancy can be noted in *figure 3* for the predicted trajectory, in that burnout was estimated at 125,000 feet, then, following a zero-lift trajectory, maximum altitude was to be 135,000 feet. At burnout I maintained 10° rather than 0° angle of attack which, combined with a slightly higher flight-path angle, modified the trajectory sufficiently to allow reaching the predicted maximum altitude. Confidence in our analog simulator work, which indicated satisfactory stability at low dynamic pressure, was one of the reasons for maintaining the 10° entry angle of attack rather than going to zero lift over the top. The dynamic pressure going over the top was 10.6 pounds per square foot at a Mach number of 1.65, and the aircraft response was slow but positive. An angle-of-attack oscillation of $\pm$ 3° with an 8-second period persisted over the top, but was hardly noticeable in the cockpit except for movement of the angle-of-attack needle. After passing peak altitude, I concentrated on stabilizing for the reentry. As the dynamic pressure increased, the pitching oscillation damped and the aircraft rotated easily to a maximum 2.6g, arriving level at 50,000 feet. The peak reentry Mach number was 2.5.

During the coast period over the top, the aircraft was at less than 0.1g for approximately 43 seconds and less than 0.2g for more than a minute. The stabilizer deflection required to maintain the angle of attack during the entry was 20°, out of 35° available. After leveling out, I concentrated on performing additional pulses during the deceleration, then finally turned toward the lake, arriving overhead at 28,000 feet. The landing was routine, after a flight time of about 11 minutes.

I will end with a few impressions of the handling qualities of the X-15. With three-axis dampers operating, the X-15 aircraft has excellent handling qualities in the region in which we have flown, including the approach and landing configuration. The rolling tail for lateral control, combined with the symmetrical vertical surfaces, provide an aircraft which is relatively free of control cross-coupling problems in the speed and angle-of-attack regime investigated thus far, although at higher Mach numbers and angles of attack we expect the coupling problem may become more severe. With the lateral-directional dampers off or failed, however, a region of dynamic uncontrollability was predicted and has, in fact, been experienced in flight. Joe Walker will mention this in more detail during his portion of this report.

The *Pioneer* XLR-99 engine. Although only 72 inches long, the engine produces 50,000 pounds of thrust at sea level. When running, it continuously monitors its own performance for safety in operation.

The XLR-99 Engine

The X-15 flight trials described in the accompanying article, were all carried out on an aircraft fitted with the interim engine. On November 15th, 1960, the first flight was made by an X-15 powered by the *Thiokol Reaction Motors*' XLR-99-RM-1 rocket engine.

During this flight, North American Aviation test pilot Scott Crossfield reached a maximum speed of 2,000 m.p.h. and a maximum altitude of 80,000 feet. The motor was not operated at peak power during the flight.

The XLR-99-RM-1 *Pioneer* is a controllable thrust engine which operates on liquid oxygen and anhydrous ammonia. The fuels are fed into the thrust chamber by a turbopump driven by the decomposition products of 90 percent hydrogen peroxide. During operation, the thrust level can be varied by the throttle lever over a range of 25,000 to 50,000 pounds thrust at sea level, and the engine can be stopped and restarted any number of times in flight.

The principal performance characteristics of the *Pioneer* engine are as follows:

Thrust	58,700 pounds
Specific impulse	284 sec
Dry weight	910 pounds
Length	72 inches

The successful flight of the *Pioneer*-engined X-15 marks the beginning of a new stage in the research program. Trials to date have explored the limit of the capabilities of the smaller XLR-11 engine. In the coming months there will be a steady expansion of the performance envelope as experience is gained with the three times more powerful engine. Speeds of 4,500 m.p.h., Mach 6 to 7, and altitudes of more than 250,000 feet will be the target for the X-15. These manned flights, outside the atmosphere of the earth, will be the forerunners to the development of the Dyna-Soar and to later piloted orbital vehicles.

• J. A. Walker, NASA

I should like to begin with a brief résumé of the four flights leading to, and including, the maximum-speed flight of the X-15 with the interim engine, and then discuss some of the results obtained to date.

Expansion of the envelope - speed

The first flight of our program was accomplished on March 25th, 1960. After many static simulator runs, F-104 landing approaches, engine and APU ground runs, and a complete mission dry run on the ground under the wing of the B-52 mother ship, I felt adequately prepared for my familiarization flight in the X-15. This first flight should have been routine, but the sequence of events made this day an extremely long and, at times, anxious one. Numerous mechanical difficulties delayed the launch approximately seven hours. When launch did occur, the roll damper was inoperative and three starts were required to light the upper engine; however, the remainder of the flight was comparatively uneventful. With this familiarization flight completed, I felt that we were well under way in our envelope-expansion program.

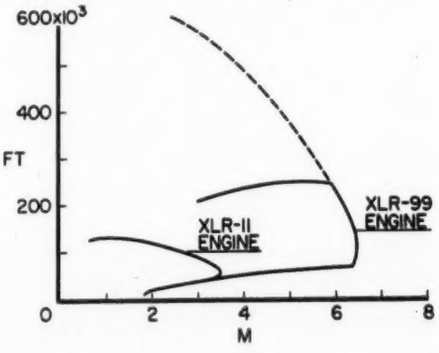
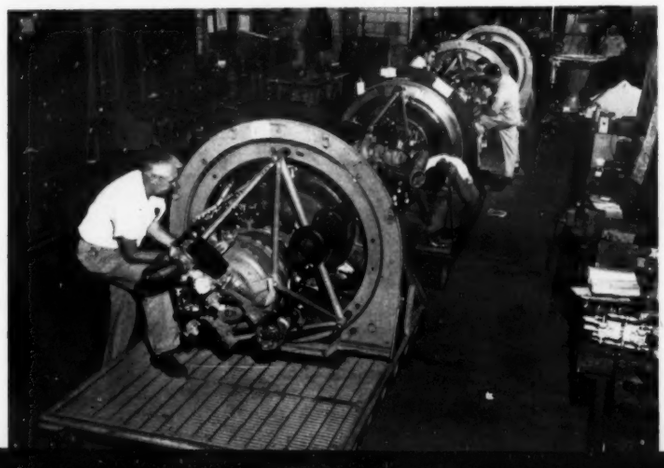


Fig. 1. The performance curves of the X-15, plotted in terms of speed and altitude for the two engines.

The next flight was accomplished with fewer mechanical difficulties; however, at a Mach number of 2.2 and 10° angle of attack, a noticeable divergence was building up when steady flight was attempted with the lateral-directional dampers off. Engaging the stability-augmentation system damped out these motions, and the flight continued without further incident. This flight indicated that a region of uncontrollability, with the unaugmented control system, probably did exist. I will cover this subject in more detail when discussing subsequent flights and the results of the program.



Four engines in various stages of assembly at the constructor's plant.

The third speed-buildup flight was launched from Silver Lake and proceeded without incident. A yaw pulse performed at Mach 3.1 with lateral-directional dampers inoperative indicated that the aircraft was stable at 4° angle of attack. Stability augmentation was again engaged, and a 10° angle-of-attack left turn was initiated. Roll and yaw dampers were disengaged and a lateral pulse was accomplished at a Mach number of 2.5. However, this appeared to trigger an oscillation which was divergent, and the inoperative augmentation channels were re-engaged to damp out the oscillation.

This flight indicated that the climb procedures and performance check points developed from simulator runs were near optimum for a maximum speed effort. The stability implications were that with dampers operating no divergences would occur. With dampers inoperative, a high-angle-of-attack uncontrollability area probably existed, but a push-over to moderate angles of attack would damp any divergent tendencies.

With satisfactory performance, stability, and control demonstrated during the buildup flights, we felt sufficiently confident to make the all-out attempt to obtain maximum speed. This flight, however, was delayed for approximately three months as a result of three consecutive unsuccessful launch attempts and the explosion that occurred on the number three aircraft. During this time I had been wondering how well I would be able to fly the aircraft after an extended lay-off from actual X-15 flight experience, particularly a flight requiring adherence to an optimum profile. I was pleasantly surprised to discover that practice on the flight plan and working out flight-plan details by using the ground simulator, plus flight practice with the F-104 for glide and landing approach, is a good substitute for a flight in the X-15 itself. I believe that these activities contributed in a great measure to the ability to fly the profile schedule as desired and in accordance with the flight plan.

Fig. 2. Simulation of the X-15 approach and landing with the F-104. The two upper curves compare the lift/drag ratios of the X-15 in the clean configuration, and the F-104 with speed brake extended and idle r.p.m. The lower curves represent the X-15 in the landing configuration and the F-104 with take-off flap, undercarriage and speed brake extended and idle r.p.m.

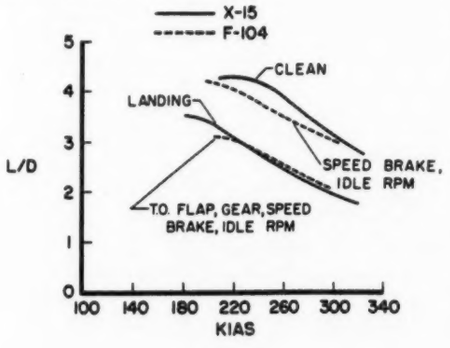
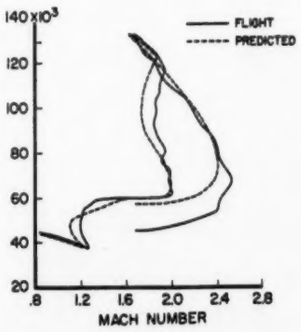
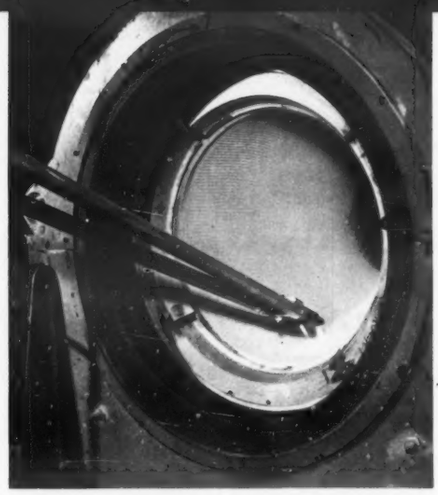


Fig. 3. The actual (continuous line) and the predicted (broken line) flight profiles for the maximum altitude flight.





A heat-resistant ceramic coating is applied to the interior of the thrust chamber. Combined with regenerative cooling, the coating virtually eliminates the possibility of burn-out.

The maximum-speed flight was made on August 4th, 1960. The launch was from Silver Lake at an altitude of 45,000 feet and a Mach number of 0.82. *Figure 4* shows the altitude-Mach number profile of the flight. During the engine start, the angle of attack reached about 10° and was checked there at the onset of buffet. The aircraft dropped to 38,000 feet and then began to climb. A relatively large unstable trim change exists between Mach 1.2 and 1.5. However, no difficulty was encountered in maintaining an 8° angle-of-attack climb schedule for maximum lift-drag ratio. At 75,000 feet and a Mach number of 2.2, push-over to zero g was initiated and it was observed that as the angle of attack approached zero a slow lateral oscillation developed. The oscillation tended to reduce in amplitude as the angle of attack and pitching velocity approached zero. At the peak altitude of 80,000 feet and a Mach number of 2.6, the aircraft was rotated to 0.5g and was maintained at this level for the remainder of the powered flight. During the acceleration to maximum speed, a gradual, increasing dive angle was obtained. The aircraft felt good about all axes, but had a slight tendency toward minute lateral residual oscillations. Burnout occurred at an altitude of 69,000 feet after the Mach meter had pegged above 3.5. Later, I was somewhat disappointed to learn that this was corrected downward to 3.31 from internal recordings and radar data.

Fig. 4. The actual and predicted profiles for the maximum speed flight. The prediction (broken line) differs from the actual during the initial climb because of wind gradients, non-standard day conditions and probable errors in drag values used in the transonic region.

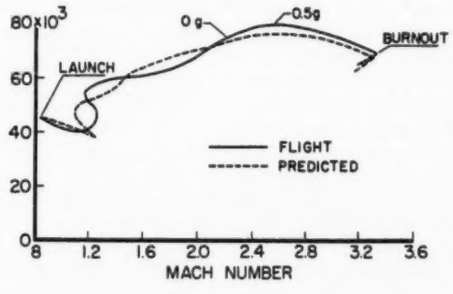
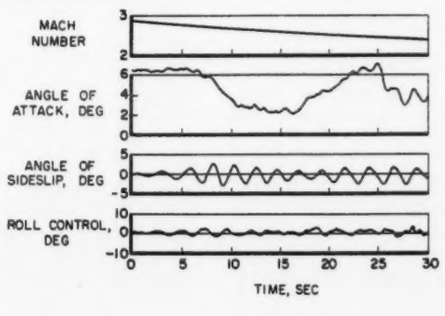


Fig. 5. The time-history of the control divergence with the roll-yaw dampers off. From top to bottom the four panels record Mach number, angle of attack, angle of sideslip and roll control.



After burnout, a 5-second coast period was maintained at 0.5g in order to obtain drag data. During a 4g pull-up, the aircraft responded with good control, but a tendency toward small directional oscillations was noted. The nose was then lowered to 1g flight, and two directional pulses were made at 4° and 10° angle of attack with the lateral-directional dampers off. Again, it was evident that the lower angle-of-attack pulse was slightly damped and the high angle-of-attack pulse tended to diverge. The remainder of flight was made without incident, and the landing was accomplished on the dry lake at Edwards.

Results and subsequent flights

The fact that reasonable correlation exists between wind-tunnel and flight values of the longitudinal, directional and lateral stability parameters has helped immeasurably in flight planning and in predicting critical test areas. The control-divergence regions mentioned earlier that have occurred during the flight program were predicted on the ground simulator by using the wind-tunnel values of stability and control derivatives. The flight plan of flight 11 requested that a deliberate attempt be made to fly in this uncontrollable region, with roll-yaw dampers off. *Figure 5* shows a time history of pertinent parameters during this deceleration after burnout. At Mach 2.9 at an angle of attack of 6°, the roll-yaw dampers were disengaged and the sideslip motions began to diverge. Recovery was effected by pushing over to the lower angle of attack. A second pull-up was performed with the same results and again had to be damped by reducing the angle of attack to a more stable region.

The performance capabilities of the interim engine are not sufficient to achieve critical heating. However, significant levels of aerodynamic heating have been obtained. Prior to one of the high-speed flights, a temperature-indicating paint was applied to various portions of the aircraft. To illustrate visually the heat variations over the exterior surface, this paint retains a pattern corresponding to the maximum temperatures encountered during the flight.

The most useful function of the paint is in defining or verifying the location of areas of concentrated heating, such as the leading-edge expansion joints on the wing. Examination shows that wedge patterns are formed downstream of the leading-edge joints and reaction-control nozzle. Similarity between the wedge-shape paint patterns to patterns found in boundary-layer-transition studies suggests that the expansion joints and reaction-control nozzle are causes of boundary-layer transition.

I would like to conclude by stating that higher-performance vehicles can be successfully designed with the human pilot utilized as an integral part of the control loop. Flying such aircraft is no longer fun, as was the popular description in bygone days. It is now serious business, with numerous restrictions involving pilot protection, instrumentation of the pilot, technical preparation, and many more items of this sort. What keeps us going is the satisfaction derived from participating in a pioneering effort for the advancement of information derived from flight. We hope to capitalize on this pioneering spirit for further advancement. ←→

A Common System for Radar Control of Civil and Military Air Traffic

A paper entitled "The Application of Radar to Air Traffic Control" was presented by the Guild of Air Traffic Control Officers at its third convention in Bournemouth on October 18th and 19th, 1960. Prepared by the members of the Guild, the paper constitutes a proposal of the Guild to meet special requirements within the United Kingdom. As some of the thoughts expressed, however, are of fundamental nature, the paper is published here as a basis for further discussion. Ed.

The basic demands made on an air traffic control organization serving both military and civil operations are the guarantee of safe separation between aircraft in flight and an effective approach and departure system at terminal airfields. These two demands would be easier to satisfy if both civil and military flying were conducted under the same rules and regulations and were restricted to considerations of one particular state only. The application of radar to air traffic control presents a threefold problem: *civil* operations, *military* operations and the *limitations* of radar application itself.

To satisfy civil needs, civil air operations are tied to a fixed route system of airways and control zones, within which safe separation is guaranteed by procedural methods. In the remaining airspace, which falls within the Flight Information Regions, military operations take place alongside any civil flying for which the airways system does not supply the necessary fixed routes.

Because of its defence role, military flying requires a certain operational flexibility which is opposed to the use of fixed routes and procedural control methods. To this end it has been the practice for military air traffic control to operate on an airfield basis within a loose air traffic control centre organization, under much tighter command operational control. Since the introduction into military service of aircraft possessing high operational performance, the location of military airfields has caused a large degree of approach pattern violation. It has therefore become urgent to set up a form of centralized control, if an acceptable degree of flexibility is to remain.

The difference in requirements between military and civil operations is obvious. On the one hand there is the scheduled civil operator who requires established and protected routes for his pre-planned and forecastable operations; on the other hand there is the military operational commander who requires a large element of tactical freedom with a minimum of preplanning and without the restrictions imposed by a standard procedural control system. This conflict is not only civil/military but also military/military. In regard to the latter, the development of centralized control agencies within the military organization could probably produce a planned system compatible with the systems employed in civil practice. With regard to the civil/military conflict, a common controlling medium is required, and the only known factor for the foreseeable future is considered to be radar.

In fact radar has become such a popular method of resolving traffic conflictions that equipments have tended to spring up like mushrooms, with varying wavebands, power outputs and areas of coverage. In the United Kingdom they are operated by the Ministry of Aviation, Air Ministry, Admiralty, municipalities, manufacturers and private airfields. A reliable estimate at the present time gives a total of 300 radar equipments deployed within the United Kingdom, almost half of which have ranges of more than 50 miles and height coverage of 15,000 feet and above. In a number of instances coverages overlap, and a situation can and does arise where two different authorities, using two different types of radar sited in different geographical positions, exercise control or proffer advice about the same portion of the airspace. It is obvious therefore that radar coverage is one thing, but utilizing it for control of aircraft is another.

At any one time there are likely to be between 300 and 400 aircraft in the airspace of South Eastern England alone, and it is a great problem to assess and identify the resulting mass of radar information, coordinate it and apply it to the need. Today even civil aircraft types vary in speed from 120 to 500 knots and in rate of climb and descent from 300 to 3,000 feet per minute. Many of these aircraft fly on opposite headings, and only a relatively small number will be in level flight. This is very simply and briefly the complex situation which the control officer is to rationalize with radar as his aid.

Radar is a medium which is as much a part of air traffic control as radio telephony, and it has in fact become the cornerstone of present-day operating techniques. But this medium should be introduced gradually, so that by learning from experience through evolutionary stages a store of empirical knowledge can be accumulated.

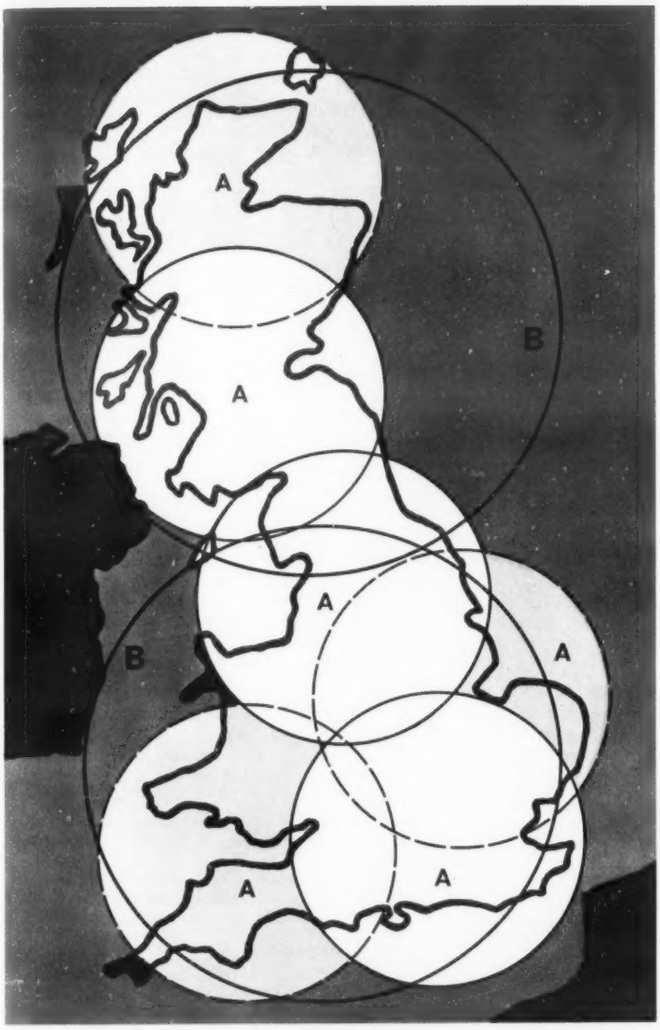
It is reasonable that the civil and military approach to the utilization of radar should differ in accordance with respective methods of operation. The civil fixed route system lends itself to planned operation and in the main satisfies the needs of civil operators. It is unlikely that any new system based entirely on radar methods will be accepted unless it is as reliable and dependable as the present procedural method. Thus radar becomes initially a supporting agent, as a first step towards eliminating the fundamental faults of the current control system. These faults primarily stem from the fact that the majority of airways are bi-directional, with the result that aircraft bound for destinations within a terminal area and wishing to descend are immediately opposed by traffic departing from the terminal area via the same route and requiring to climb. This particular problem of aircraft opposing each other and virtually on the same track—in the absence of a precise navigational aid—is undoubtedly one of the most difficult facing the radar controller at this time. Here there is a built-in collision hazard, which the radar controller must resolve before he can commence his prime task of guiding aircraft through occupied levels. As a first requirement, therefore, it is imperative that this severe limitation to the direct application of radar control should be eliminated by revising the routeing structure both within terminal areas and along the routes. Only by eliminating head-on en-route conflictions and crossing tracks wherever possible can the radar controller fully exploit the potentialities of his equipment.

The principal military problem, however, is the separation of aircraft operating from airfields with overlapping approach patterns which cause delays, hazards and loss of operational efficiency because of the resulting complicated and time-consuming procedures. Here, the requirement is for a comprehensive system of area control which would apply radar as the prime agent to rationalize and coordinate airfield approaches and departures and thus to achieve adequate separation of all known traffic.

The pattern thus becomes twofold. Firstly, the application of radar control in support of a planned procedural system, such as is currently in operation, leading eventually to a control system utilizing a precise navigational aid as a back-up to the primary use of radar; secondly, for the airspace outside the prescribed route system, the application of radar as the prime controlling agent, introduced gradually area by area.

To carry out this task, both civil and military radar controllers initially require radar coverage in their areas of responsibility from approximately 5,000 to 25,000 feet, backed up where necessary by airfield radars to cover the approach and departure phases. However, as increasing numbers of both civil and military aircraft are operating above this height, universal coverage of the airspace from 25,000 to 60,000 ft-plus is required, and high-looking radar should be made available to both civil and military controllers operating from combined air traffic control centres. It is in this particular airspace, the Guild believes, that the first steps can be taken to create a combined civil/military air traffic control system.

To be successful, radar equipment should be not only designed for these specified tasks but also sited at the appropriate geographical locations.



The British Guild of Air Traffic Control Officers believes that a comprehensive air traffic control organization in Great Britain could manage with eight radar systems. Three combined civil and military control centres would have equipments with medium coverage (A, white circles), and two of these control centres would also have long-range radars (B). Three purely military control zones are also planned (A, grey circles).

Through force of circumstance it has been necessary in the past to use radar equipment designed for a military role and sited to meet military operational requirements; but if the ATC problem is to be solved by radar, then it can be done only by using the right equipment for the job. For the purpose of this paper it is assumed that the necessary radar coverage should be obtained with the aid of the minimum number of equipments. Two basic radar types are required.

Type I should provide coverage from a defined lower level (perhaps 5,000 ft) to 25,000 ft, with a positive range of 150 nautical miles.

Type II with a coverage from 15,000 to 60,000 ft-plus; positive range 250 nautical miles.

Both the above equipments must meet the following basic specifications.

24-hour operation: This requires the provision of back-up equipment and facilities to cater for maintenance and for radar or power failures;

Removal of all weather and permanent echoes, but with facilities for re-introducing weather returns so that aircraft can be vectored around dangerous weather situations;

Elimination of interference generated either within the equipment itself or by an external source. The Guild considers that there should be a central licensing authority to which organizations planning to deploy radar equipments should be required to apply for approval;

Reduction, or if technically possible, elimination of tangential and blind velocity fades: At present, in spite of MTI, radar echoes can fade when aircraft are flying in certain directions and at certain speeds. This fading can be anticipated to a certain degree, but is nevertheless disconcerting;

A minimum scanning rate of 10 r.p.m.: At 600 knots an aircraft travels 10 miles in one minute, one mile in 6 seconds. On initial radar pick-up a controller requires at least three returns before he can accurately assess the direction of flight and, even ignoring the need for identification, allowance must be made for thinking time on the part of controller and pilot. It has been reliably calculated that it takes 7 seconds after the pilot has moved his controls for an aircraft travelling at 120 knots to move 10 ft in azimuth. It would be interesting to calculate how long this would take if the aircraft were flying at 600 knots, and how far the aircraft would have travelled. The situation becomes more complex if autopilots are used, and much research is necessary to assist radar controllers in their task of protecting high-speed aircraft;

The minimum beamwidth should be 2 degrees, even at the risk of reduced discrimination; the size of the radar return is of great importance, as it directly affects controller fatigue and therefore the length of time a controller can usefully operate from a radar display;

The area of operational coverage must be gap-free: Radar coverage areas are not always solid envelopes, and with present equipments it is quite possible for an aircraft which climbs too quickly and too soon to "ride up" in a finger gap and disappear from the radar screen for a considerable portion of its flight;

Automatic height extraction: It is suggested that it would be more useful to isolate height bands of airspace rather than have an absolute height identification for any particular aircraft. The accuracy of an automatic height extraction device should be in the order of at least $\pm$ 1,000 ft;

Video mapping: One of the greatest difficulties facing the radar controller is the constant surveillance of the mass of radar returns which appear on his tube. Much of this difficulty can be overcome by providing a series of video maps which can be superimposed on his display as required. These maps should show fixed routes, climb-out and entry tracks to terminal areas, controlled airspace, danger areas and any other useful information. The controller should be able to select information applicable to the scale or sector on which he is working;

Automatic identification to be provided by secondary radar working in conjunction with the primary radar. This presupposes international agreement on the carriage of the necessary airborne equipment;

Automatic transfer of radar information: Once an aircraft has been identified on the screen of one controller, it must be possible to transfer the information automatically to another radar screen;

Radar consoles should be built up of units which can be assembled by simple plug and socket connections; facilities for aerial head selection should be included. A special study should be made of the best layout of the controls.

Having discussed the types of radar required and their specifications, let us now consider their deployment. On the one hand, the radar operations room can be located at the radar site, in which case the deployment of equipments depends on factors other than radar coverage; on the other, it can be situated away from the radar at a point which is organizationally convenient, in which case the choice of radar site can be based on considerations of coverage only. The Guild favours the second solution and feels that radar information should be fed to air traffic control centres where it can be matched against all relevant movement information.

In the United Kingdom, information from type I radars (5,000 to 25,000 ft) could be fed to the three combined air traffic control centres at London, Preston and Prestwick. As these centres are also the junction points for all civil and some military movement information, all necessary data for effective route control in a given area will thus be available at a centralized location. However, the cover obtained from the civil radars would primarily embrace the airways system, and although there would be some spare cover which would assist in military radar operations, it is unlikely that this could completely satisfy the military requirement. At least three military areas would probably be required, covering firstly the Vale of York, northeast England and southeast Scotland, secondly East Anglia, and thirdly south and southwest England.

Information from type II radars (15,000 to 60,000 ft) may be required at only two of the combined air traffic control centres.

The foregoing considerations suggest that a radar organization could be built up on the basis of six type I and two type II radars, with three combined air traffic control centres (two of them having type II as well as type I radar) and three military radar areas with type I radars, working in cooperation with the three combined centres.

It is not possible at this stage to discuss the manner in which such an organization would operate, for much will depend upon international agreement and the existence of a comparable control system adjacent to United Kingdom airspace. However, the suggested facilities and organization would serve as a framework for the construction of a system compatible with present and future military and civil operations. ←

What's in the Air?

AIRCRAFT AND ENGINES

Under the so-called Wagmite programme for the U.S. Navy, design specifications have now been released for an inflatable twin-turboprop V/STOL aircraft. The specifications call for an aircraft weighing some 15,000 lb; fuel carried would weigh about 3,900 lb, and the payload would be about 3,000 lb. The body and wing would be manufactured out of neoprene fabric. Length would be 43 ft; span 36 ft; cruise speed 370 m.p.h.; range more than 500 st.miles. The suggestion is that a number of such inflatable aircraft should be stored (e.g. on submarines) and equipped for low-level attack work.

The Beechcraft production line for 1961 comprises eight different models: the newly introduced five-seat Beech Model 55 *Baron* ($58,250 in its standard version) plus the 1961 models of the *Super G18;* the Model 65 *Queen Air;* the N35 *Bonanza;* the J50 *Twin Bonanza;* the D50E *Twin Bonanza;* the A33 *Debonair;* and the *Travel Air*. The new Beech *Baron* is powered by two 260 h.p. Continental IO-470-L engines. Take off and landing weight 4,880 lb; useful load 1,920 lb; range with full payload 870 n.m.; economical cruising speed 187 knots at 65 percent power.

The Procaer F.400 Cobra two-seat sports and touring aircraft, powered by a Turboméca *Marboré IIF* jet with 880 lb thrust, has begun flight tests at Milan-Malpensa Airport. The F.400 *Cobra*, illustrated on this page, is designed for unlimited aerobatics and meets the U.S. CAR 3 4b and British AP 970 specifications. The *Cobra* has a skin consisting of plywood panels covered with aluminium for maximum smoothness. This type of structure is a Procaer development and has already proved successful in earlier aircraft such as the F.15 *Picchio*. In other respects the *Cobra* is of conventional construction, with a single-spar, one-piece wing with laminar airfoil and simple tail unit. Landing flaps, aerodynamic brakes and undercarriage are actuated hydraulically; maximum landing flap deflection 45°; air-conditioned cabin. One 88 Imp. gal. fuel tank in the fuselage, two others, capacity 16.5 Imp.gal., in the wings; auxiliary tanks with 22 Imp.gal. capacity each can be mounted at the wingtips. Electrical system 24V, 800W; complete instrument flying equipment (two VHF transmitter/receivers; ADF). Main dimensions and weights: span 28.5 ft; length 26.4 ft; wing area 127 sq.ft ; aspect ratio 6.5. Weight empty 1,980 lb; useful load 1,100 lb for aerobatics or 1,550 lb for normal flight; all-up weight 3,080 lb for aerobatics or 3,530 lb for normal flight. Design performance: maximum sea-level speed about 300 knots; cruising speed at 13,120 ft about 280 knots; sea level rate of climb 3,150 ft/min; service ceiling 25,000 ft; range 540 n.m. with normal fuel supply or 700 n.m. with auxiliary tanks.

SNECMA Atar 9C static, altitude chamber and flight tests are proceeding at an accelerated rate to enable the engine to be ready in time for the official 100-hour type certification tests, which are contractually scheduled for January, 1961.

The Fennec now in service with the French Air Force is equipped with four 12.7 mm cannon or two bombs plus Matra 38 rocket launchers. The aircraft is a SFERMA conversion of the North American T.28 and is replacing T.6s in service with the Air Force in North Africa. Powerplant is a Wright R-1820-56S of 1,300 h.p. with a three-blade Hamilton Standard propeller in place of the T.28's original 800 h.p. engine and two-blade propeller.

A prototype of the Grumman W2F Hawkeye, developed as a successor to the WF-2 AEW aircraft in service in large numbers with the U.S. Navy, has begun flight tests. Considerably larger than the WF-2, the *Hawkeye* is powered by two 4,050 e.s.h.p. Allison T56-A-8 turboprops and carries a General Electric radar in a dish-shaped "Rotodome" (rotation speed 6 r.p.m.—diameter 20 ft) over the fuselage. The wing span of the *Hawkeye* is 80 ft 7 in.; length 56 ft 4 in.; maximum take-off weight 49,500 lb. The main task of the new aircraft, for which Grumman expects substantial quantity orders, will be radar early warning for large naval units.

General Electric reports that its CJ-805-3B commercial turbojet has been certificated by the Federal Aviation Agency for installation in the Convair 880-M. Take-off thrust rating is 11,650 lb and maximum continuous cruise rating 9,800 lb.

The three- to five-seat Czechoslovak HC-3 helicopter, several of which are already undergoing tests, is of all-metal construction and has a three-blade rotor with a blade control device developed by engineer Slechta; a three-blade tail rotor; a four-legged undercarriage (which can be fitted with skids or floats if required); and small tail stabilization surfaces. The powerplant is a 240 h.p. M.108H piston engine, fitted with a fan wheel for cooling. The HC-3 can be fitted with equipment for a variety of roles and also with dual controls for training. The technical data are as follows: maximum sea level speed 86 knots; maximum oblique rate of climb 984 ft/min; hovering ceiling within the ground effect 6,560 ft; service ceiling 13,780 ft; range 170 n.m. Empty weight for all versions 1,980 lb; all-up weight varies between 2,645 lb for the trainer version to 3,090 lb for the agricultural and freight version.

ACCESSORIES AND EQUIPMENT

OmniRay AG, of Zurich, as representative of the F.L. Moseley Company in Switzerland, sells the Model 2S, 3S and 2D XY recorders. These record two values, X and Y, in Cartesian coordinates. The 2S and 3S recorders indicate d.c. voltages; the Model 2D can record both d.c. and a.c. voltages at frequencies of up to 200 kc/s.

Canadian Applied Research Limited, of Toronto, is producing two new 35 mm electrical recording cameras for use on the ground and in the air, for use in the field of instrumentation, aerial survey positioning and radar photography.

A new honeycomb core material, known as *Trussgrid,* has been developed by General Grid Corporation. *Trussgrid* is fabricated of aluminium alloy 5052 by Aluminum Company of America.

Pintsch-Bamag AG, of Berlin, with branches in Cologne and Butzbach, Hessen, manufactures airfield lighting systems, searchlights, cloud altimeters and power supply units.

A major advance in ammunition design has been made with the development of a combustible cartridge case that burns completely when fired in a gun. Scientists at the Armour Research Foundation, Chicago, cooperated in designing the material (composition of which is classified) under a contract with Picatinny Arsenal and the Ballistic Research Laboratories. The new material eliminates the need for expensive brass shell cases and lightens the weight of each round. It not only minimizes gases released from the fired ammunition, but leaves no residue in the gun barrel after firing.

SPACE RESEARCH

NASA Project S-51 is an Anglo-American satellite for ionospheric research, known in Great Britain as *U.K. Scout I* and in the USA as *International I.* Research groups at Birmingham University and at Imperial College and University College, London, are developing the instrument payload under the direction of the Royal Society's National Comittee on Space Research; instrumentation will include equipment to

Three U.S. all-cargo operators, Seaboard & Western, The Flying Tiger Line and Slick Airways, have ordered the Canadair CL-44 swing-tail cargo transport. Flight testing began last November, and type certification is scheduled for spring 1961. Streamlined fairings encase the swing-tail hinges.

Lockheed JetStar *executive transports will appear in service with business corporations and Government agencies in 1961. First deliveries are scheduled for early in the year. The* JetStar *is powered by four Pratt & Whitney JT-12A-6 (J60-P-5) engines of 3,000 lb thrust each.*

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measure electron density and investigate solar radiation in the ultra-violet and X-ray ranges. Pye Limited and the Guided Weapons Division of Bristol Aircraft have received contracts to build some of the equipment. The Goddard Space Flight Center at Greenbelt, Maryland, is responsible for the satellite body, telemetry equipment and power supplies. Cylindrical in shape with hemispherical end bulkheads, the satellite is 23 in. in diameter and weighs 150 lb. Solar cells are carried on four paddle-shaped mounts. A four-stage *Scout* booster will put the satellite into an orbit with an angle of 55°, a perigee of 200 miles and an apogee of 600 miles. It will circle the earth for about a year.

NASA has selected three companies to perform feasibility studies of the *Apollo* advanced manned spacecraft: Convair Astronautics Division of General Dynamics Corp.; General Electric's Missile & Space Vehicles Department; and The Martin Company. Each company will conduct a six-month study to define a manned spacecraft capable of circumnavigating the moon, including a proposed development programme with time, costs and facilities estimates and indication of technical aspects of the programme requiring long-term research and development work. Avco Corp.'s Research and Development Division will be associated with Convair Astronautics in the study programme. Convair will handle preliminary vehicle design, while Avco will be responsible for solutions to re-entry problems and for exterior design. One of the primary tasks of the three main firms concerned is an evaluation of the radiation hazards to man in the outer radiation belts around the earth. Both NASA and ARPA intend to carry out research with this objective. NASA wants to launch the *Thor-Delta* rocket with a 100 lb instrument payload into a near-circular orbit with a 1,500 mile radius; ARPA would use an *Atlas-Agena B* carrying animals and instrumentation.

The Fédération Aéronautique Internationale will in future recognize space flight records, for the highest altitude, longest duration and greatest orbital weight. Proof of performance must be furnished by instruments and observation, and earlier records must be beaten by at least 10 percent; the occupants of the space vehicle must return to earth unharmed.

INDUSTRY

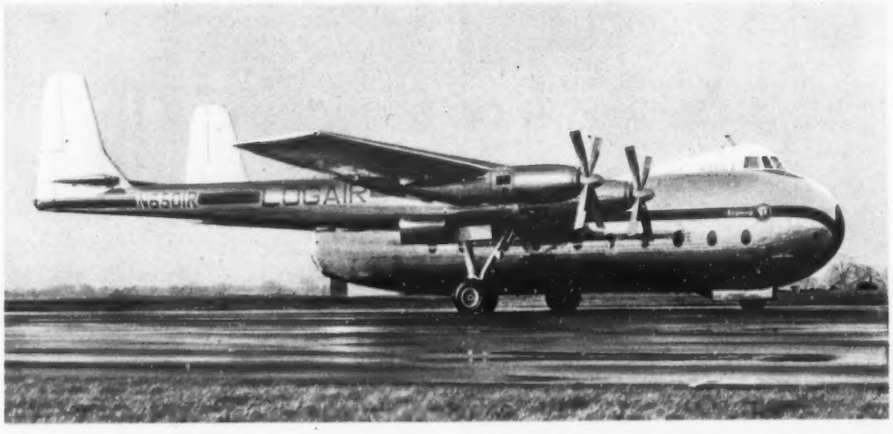
North American Aviation sub-contractors reinstated in December for the B-70 *Valkyrie* programme included Garrett Corporation's AiResearch Manufacturing Division for the central air data flight system, and Beech Aircraft Corp. for the alert pod. The B-70 wing has been switched from Boeing to Convair, but the USAF has indicated that there will be no further major changes in the original sub-contracting structure. The Defense Department has approved $265 million funding for the fiscal 1961 B-70 programme, an increase of $155 million on the original allocation for this year.

Boeing of Canada Ltd. is the new name of Canadian Vertol Aircraft Ltd., of Arnprior, which has been reorganized by the parent concern, Boeing Airplane Co. Roy G. Peers and Leonard W. Brockington have joined the Board. Last year Vertol made a strong bid to sell the 107 to the Canadian Government, but the long-awaited decision on helicopters to be ordered for the Canadian armed forces is still deferred.

The French National Assembly has approved a NF 640 million ($128 m.) budget for civil aviation in 1961, a cut of 20 percent on the 1960 allocation. The 1961 programme includes: NF 40 million for *Caravelle* development (Sud-Aviation); NF 21 million for the Breguet 941/942; NF 15 million for the *Super Broussard* (Nord-Aviation); NF 10 million for supersonic transport studies.

The French ODE organization has decided to organize a second International Light Aircraft Show, following the success scored at Oran last October. The 1961 show will be staged at Cannes-Mandelieu Airport for a period of ten days in the last half of May. The 24th Paris Air Show at Le Bourget (May 26th—June 4th) will also feature a light aircraft section.

De Havilland Aircraft (HSG) has booked orders for four more *Comet 4Bs* for British European Airways' European and Middle East Services, bringing the total *Comet* order book up to 60 aircraft. The company handed over the first of four *Comet 4Cs* on order for Middle East Airlines in December.



Miami cargo operator Riddle Airlines Inc. took delivery of the first of seven Armstrong Whitworth (HSG) AW.650 turboprop freighters in December. Delivery will be completed by April. The order is valued at $12 million, and the carrier has taken an option on a further eight AW.650s. Riddle has recently received a $25 million MATS Logair contract.

Three-view drawings of the Boeing 727 short-medium haul passenger transport which will go into production for Eastern and United Air Lines. Span 108 ft, length 134 ft 1 in. Wing sweep 32° at quarter chord. Powerplant three Pratt & Whitney JT8D-1s of 14,000 lb thrust each.

Options on 17-20 Vickers-Armstrong VC.11s have been taken by Trans-Canada Air Lines, with the final order expected to total about 50 aircraft. Lufthansa is also reportedly showing strong interest in the VC.11 as a Convair replacement. Another possible customer is Continental Air Lines who will be in the market for Viscount 800 replacements. Vickers' design and development work on the VC.11 is being accelerated. Progress has been facilitated by the fact that this is virtually a scaled-down VC.10, with four Rolls-Royce RB.163s and blown flaps.

Rolls-Royce Deputy Chairman and Chief Executive J. D. Pearson has called for increased Government financial support for the British aircraft industry to meet what he called a fight for survival in world markets. Pearson said that Rolls-Royce has recorded £230 million in export business over the last seven years, and the company's engines are now powering over 1,000 civil aircraft in service or on order throughout the world. Selling engines for the next 1,000 aircraft will be difficult, and the cost of developing and launching a modern large aircraft engine is now about £20 million, almost equal to the cost of the airframe. An investment of this order is unlikely to be recovered

Montreal International Airport's new $30 million terminal building was officially opened on December 15th. Incoming passengers are handled at ground level, and departures on the first floor. Traffic is split vertically with domestic passengers handled on the east side of the building and trans-border and foreign traffic on the west. Corridors beneath the apron area connect the aeroquay to the main building.

The Sud Aviation Alouette III *seen against a Himalayan background during recent tests and demonstrations for the Indian authorities. During these trials the* Alouette III *set up a new touchdown altitude record at 19,700 ft.*

The Sikorsky S-60 crane helicopter lifts a two-ton trailer from the Weehawken, N.J. pier for loading on a merchant vessel moored in the Hudson River. The S-60 is powered by two Pratt & Whitney R-2800 piston engines of 2,100 h.p. each, and can transport loads of 4 to 6 tons over ranges of up to 100 miles.

from a single aircraft project, and it is important to harmonize civil and military requirements.

The British Government's policy of reinforcing the aircraft industry at its points of strength has largely meant assisting companies who have shown their own ability to succeed in world export markets. Pearson pointed out that there comes a time when even these companies find that the risks and finance required are beyond their own capacity, and he made it clear that Rolls-Royce is now approaching this point.

McDonnell Aircraft Corp. and Handley Page Ltd. are discussing possible cooperation, but have both denied that the talks are aimed at a possible takeover.

The RF-01 single-seat powered sailplane, designed by René Fournier of Saint Avertin, France for an amateur design competition, is of wooden construction with plywood and canvas skin. Retractable single-wheel undercarriage with skids under the wings. Powerplant is a 25 h.p. Volkswagen engine, to be replaced later with a 35 h.p. unit.

Production of the all-metal four-passenger Piper Cherokee *will begin at the company's new Vero Beach, Florida plant this month. Powerplant is a 160 h.p. Lycoming and cruising speed is in excess of 130 m.p.h. The* Cherokee *will be on the market early this year, priced at $9,995.*

McDonnell would probably like to arrange U.K. production of the F4H *Phantom II* in which the British Navy is interested as a possible *Scimitar* and *Sea Vixen* replacement aboard its projected new carrier. McDonnell talks with Hawker Siddeley Group were broken off earlier last year.

Hamburger Flugzeugbau GmbH has abandoned its HFB.314 medium-haul twin jet passenger transport project, and has withdrawn its application for state aid for development and construction of two prototypes. The company says that the time has passed for the successful development of such an aircraft, particularly in view of the advanced competition from the U.K. and USA.

Dornier Werke GmbH has acquired distribution and servicing rights in West Germany and Switzerland for the Del Mar Engineering Laboratories towed target systems. Fairey Engineering has similar rights for the rest of Continental Europe excluding Scandinavia.

British Executive and General Aviation Ltd. has acquired the aviation business of F. G. Miles Ltd., of Shoreham Airport, Sussex. This is a logical development of the manufacturing and technical liaison between the two companies announced at the time of the formation of Beagle. Peter Masefield becomes Chairman of Miles, and F.G. Miles is Deputy Chairman. George H. Miles becomes Chief Engineer of the Beagle Group.

American Machine & Foundry Co. has established a West German subsidiary *AMF Deutschland GmbH* to market the company's products. Temporarily located in Wiesbaden, the new company will move into a leased building in Frankfurt later. Wilfried Groote, formerly AMF representative in Europe, is Managing Director. AMF also has subsidiary companies in Sweden, England, Italy, Switzerland, Canada, Mexico, Brazil, Japan and Australia.

Giuseppe Luraghi has replaced Balduccio Bardocci as President of the Alfa Romeo company, but the latter retains his seat on the board. Luraghi was formerly Managing Director of Finmeccanica, but left Government employment to return to private industry. This move matches increased Alfa Romeo activity in the aeronautical field. The company is building a new facility near Rome–Fiumicino for the manufacture of components and jet engine overhaul, currently handled at Pomigliano d'Arco. Alfa Romeo is also interested in rocket component manufacture.

CL.402 Santa Maria is Aeronautica Macchi's designation for the Lockheed LA.60 utility aircraft which the Italian company is manufacturing under licence. The first production models are expected to roll out in the spring of 1961, but no orders have been reported to date. Macchi indicates that further close cooperation can be expected to develop between the two companies in the future.

Società Italiana Telecomunicazioni Siemens SpA is the title of Siemens' new Italian subsidiary. Capital is 4,400 million lire ($7m.). The company will manufacture radio and electronic transmitting equipment, and telemetry and radio-controlled installations.

Air Vice-Marshal Ranjan Dutt has been appointed Managing Director of Hindustan Aircraft Ltd. He succeeds Air Marshal Aspy M. Engineer, recently appointed Chief of the Air Staff following the death of Air Marshal S. Mukerjee.

AIR TRANSPORTATION

New ICAO member states reported are: Republic of Ivory Coast (Nov. 30th); Republic of Mali (Dec. 8th); Republic of Senegal (Dec. 11th) and the Federation of Nigeria (Dec. 14th). 83 nations are now members of the International Civil Aviation Organization.

TWA, Trans-World Airlines, has finally completed plans to cover finance requirements for the 27 Boeing and 20 Convair 880 jets on order. Howard Hughes' 78-percent controlling interest (via Hughes Tool Co.) is to be placed in trust, and US insurance companies and banking houses will make $165 million available. A further $100 million will be raised in debentures and Hughes Tool will provide an additional $50 million if required. The lending houses will have voting control of TWA for two years. Six of the original 30 Convair 880s on order for TWA have recently been released to Northeast Airlines who is leasing both airframes and engines. Developments on the projected TWA-Northeast merger will probably follow.

British West Indian Airways' share capital, currently held 100 percent by BOAC, is to be reorganized with the West Indies Federal Government acquiring a majority (51 percent) holding. The company will be reconstituted with the remaining 49 percent divided between BOAC and Trans-Canada Air Lines.

BOAC has asked CAB for permission to add Washington, Baltimore and Philadelphia as co-terminals on its North Atlantic route, and Boston as an intermediate point. BOAC will introduce twice-weekly direct service Los Angeles–London on March 2nd, increasing frequency to three flights a week during the summer. Boeing 707s will be introduced on the London–Geneva –Tel Aviv–Teheran route on January 30th. Since early December Boeing 707s are operated on trans-Pacific services to Hong Kong and Tokyo.

British Commonwealth carriers BOAC, Qantas and Air-India are planning a 17 percent increase in capacity this year on the tripartite route network from the U.K. through India to Tokyo and Australia. Since last April pooled traffic has increased substantially and the three carriers' target revenue of £49.5 million for the first year will be achieved. Current operations cover 46 services a week to various European airports, in addition to London. From next April frequency between the U.K. and India will be 30 flights a week (BOAC 20; Air-India 6; Qantas 4). Pakistan International Airlines may join the pool.

Air France has signed a new contract for three more Boeing 707-328s for delivery in February, March and April, bringing fleet strength up to 20 (17 now in service). Air France's *Caravelle* orders now stand at 33, plus one each for Tunis Air and Air Liban. Two converted *Super Constellations* are being put into scheduled all-cargo service between Paris and New York this month.

Lufthansa Boeing 707 services on the Far East route to Tokyo via Bangkok and Hong Kong will be inaugurated on January 23rd. A Far East Regional Office was opened in Tokyo on December 1st, 1960. Lufthansa'a order for Boeing 720Bs has been increased from four to eight, bringing the jet fleet up to 13 aircraft; four 707-430s are now in service and a fifth is scheduled for delivery in the spring. The carrier is still studying short-haul jets to be acquired.

Deutsche Flugdienst, the West German charter operator, has ordered a Vickers Viscount 814 for delivery this summer. Vickers-Armstrongs (BAC) order book for the *Viscount* now stands at 425 aircraft, of which 416 have been delivered.

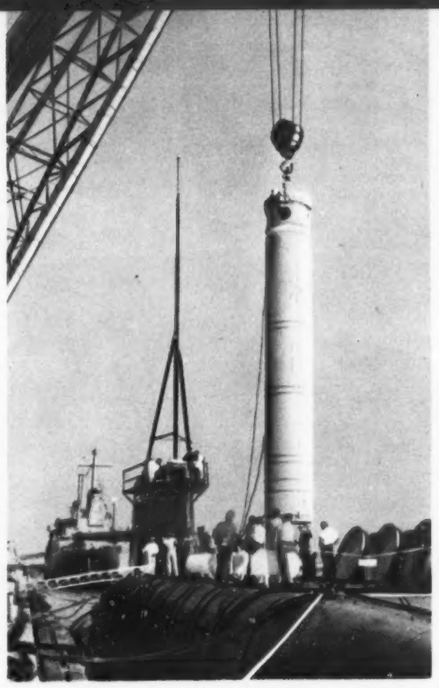
Alitalia Chairman Count Nicolò Carandini has said that the company's jet fleet will include 10 Douglas DC-8s and 14 Sud-Aviation *Caravelles* by the end of 1962. Alitalia has recently purchased 5 more Viscounts, bringing fleet strength to 14. One DC-6 and 6 Convair 440s have been sold, and 2 DC-7Cs converted to freighters. The board has agreed a capital increase from 20,000 to 25,000 million lire ($32—40 million).

El Al, Israel Airlines is chartering a Boeing 707-441 from Varig and plans to inaugurate Tel Aviv–New York service early this month. El Al has two Boeing 707-420s on order for delivery in May and June, and an option on a third.

Air-India International's third Boeing 707-420 is due back from modification in Seattle this month, with delivery of the fourth due in April. With only two 707s in service, utilization has been running at about 300 hours a month instead of the carrier's normal 250 per aircraft. Air-India may order a fifth 707 for delivery in 1962 to maintain planned schedules on the Far East route to Hong Kong and Tokyo.

Indian Airlines Corporation will receive the first of five Fokker F.27 *Friendships* on order next April. Even if the carrier's option for a further five is taken up, DC-3s will have to be operated for some time to meet schedule requirements. Some Indian Government circles favour a standardized twin-turboprop fleet for some years, to be replaced with short-haul jets in about 1965.

All-Nippon Airways, Japanese domestic operator, will send pilots to the Netherlands in March for F.27 *Friendship* training, with an aircraft chartered from KLM, Royal Dutch Airlines. Fokker will deliver ANA's three *Friendships* in May this year.



A Polaris *container being loaded aboard the FBM submarine* George Washington. *The covers of the launch tubes can be seen on the right. Lockheed is investigating the possibility of reducing the launch weight of the* Polaris A-1 *from the present 28,000 lb by the use of materials other than steel for the frame and skin and with lighter fire control, communications and guidance systems.*

MILITARY

The U.S. Air Force activated its first mobile *Minuteman* unit, the 4062nd Strategic Missile Wing, at Hill AFB, Ogden, Utah, in December. The wing will be assigned two squadrons of railroad-borne *Minuteman* ICBM weapons in 1962. Meantime, it will participate in the development of the mobile *Minuteman* programme and start a training programme for personnel assigned to its two squadrons, the 752nd and 753rd.

Hill AFB will be the site of a *Minuteman* assembly and maintenance facility which will support the mobile missiles, to be operated by Boeing Airplane Co.

F-104G Starfighter contracts will probably have been finalized between the Italian Government and Lockheed Aircraft and General Electric by the time these lines appear. Italian industry is expected to manufacture some 182 *Starfighters* with Fiat as the main contractor. The Italian Air Force will receive 100, financed 50-50 by Italy and the U.S. The balance will go to Belgium (25) and West Germany (57) as part of the joint European production programme.

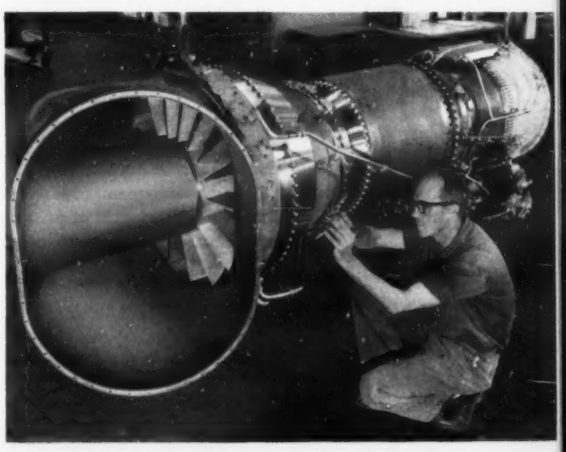
Royal Navy Fleet Air Arm Scimitar modifications for mounting *Sidewinder* guided weapons will be carried out at base airfields or on carriers. The *Scimitar* will not carry airborne radar, but will use *Sidewinders* in conjunction with the radar ranging equipment already fitted in the nose. The present armament of four 30 mm Aden guns will be removed and the *Sidewinders* mounted on wing pylons.

The final Swiss decision on the choice of either the Dassault *Mirage III* or the Saab 35H *Draken* (H = Helvetia) for equipping the Air Force is expected early this year, following a further series of evaluation tests at the end of November. The two aircraft were demonstrated to the Federal Government and National Defence Committee at the Emmen, Alpnach and Unterbach air bases. The Swiss authorities are studying technical and flight characteristics, operational and maintenance factors, procurement and manufacturing possibilities, and costs and delivery dates.

The Belgian Government has placed an order with Canadian Aviation Electronics for F-104 simulators, but details have not been released. West Germany has ordered 16 and the Netherlands 4, and CAE is also building 6 for the Royal Canadian Air Force. Negotiations are in hand with Japan and Italy.

Work is now in hand at the Hammaguir Military Base (60 miles south of Colomb-Béchar in the Sahara) on the erection of an assembly tower for launching space vehicles containing small animals. The launch vehicle will be an ONERA *Super Véronique* rocket, and the first firing is scheduled for January 1961. The ground control facilities have already been installed.

Hammaguir, which will thus have three missile launching bases and a 9,850 ft runway, is also to get two firing ranges. The first, extending 300 miles in the direction of Tindouf, will be employed for testing tactical missiles. The second, extending 1,800 miles in the direction of Fort Lamy, will be used for testing medium-range strategic missiles to carry France's nuclear deterrent. The bases will later be used by the SETEL group (European *Hawk* production) for testing the missiles built in Europe.



Pratt & Whitney's new JFTD-12 gas turbine engine is a derivative of the JT-12 pure jet engine, and is under development for aircraft, ground and marine vehicle installations. First installation will be in the twin-engined Sikorsky S-64 Skycrane *helicopter at 4,050 s.h.p. First experimental models were scheduled for delivery in late December. The FT-12 industrial version will have a maximum rating of 3,000 s.h.p.*

Installation of General Electric CJ-805-23C aft-fan engines on the company's Sud Aviation Caravelle *was completed on schedule, and the aircraft was due to make its first flight in December. A flight test programme will be launched in early 1961 to help Sud Aviation gather data for FAA certification for the* Caravelle VII. *Short-cowl nacelles have been designed and built by Douglas Aircraft Co.*

Norwegian Air Force Catalinas operated for search and rescue work are to be replaced by Grumman *Albatross*. U.S. Secretary of the Air Force Dudley C. Sharp confirmed in Oslo recently that Norway will get Lockheed F-104Gs for her Air Force. The F-104s will be manufactured in the U.S. and will be supplied under the Military Aid Programme, but deliveries may not start for some years.

The Netherlands Naval Air Arm has received the first five of 17 de Havilland of Canada CS2F-1 *Tracker* ASW aircraft from Canada. Valued at $25.5 million, the *Trackers* are supplied by Canada under the Mutual Aid Programme for NATO members.

Cold Front in International Air Traffic Negotiations

Although at their annual general meeting the IATA companies testify to the unifying force of passenger, freight, and mail transport, this does not alter the fact that air transport is a business. It is well known that business is less concerned with brotherly love than with the question of the competitors and one's own commercial progress. In times of great prosperity this question may temporarily lose some of its bitterness, a good example of this being the start of jet traffic across the Atlantic.

From optimism to hard facts

For months managerial circles on this side of the Atlantic and beyond were so impressed by the satisfactory loadings of their jet passenger aircraft that they saw the success of their competitors in a less harsh light.

But enthusiasm is gradually giving way to more sober considerations. For example, U.S. firms engaged in trans-Atlantic traffic are again remembering that the developments of the last decade have not been entirely in their favour. If in the first postwar years 70 to 80 percent of the total North Atlantic passenger traffic fell to Pan American and TWA, and to American Overseas Airways (which merged with Pan Am in 1950), and if at the beginning of the '50s their total percentage was still one half the traffic, the U.S. share steadily receded during the following years, to sink to 37.5 percent in 1959. Here are a few figures to illustrate this.

Scheduled North Atlantic passenger traffic [1])

	Passenger total	Share of U.S. firms PAA + TWA	
1950	311,150	175,021	(56%)
1951	328,764	164,608	(49%)
1954	550,000	255,297	(46.5%)
1957	988,146	412,415	(41.5%)
1958	1,190,860	438,582	(37%)
1959	1,367,287	441,174	(37.5%)

[1] These statistics are derived from a table compiled by the Institut du Transport Aérien (ITA). In the course of this article information has been obtained from other ITA studies.

The reasons for this development are so well known that long-winded explanations are not necessary. Since the North Atlantic traffic is one of the most profitable branches of the air traffic industry, all companies which had suitable aircraft crowded in on the Atlantic routes: from eight carriers in 1948 there were shortly seventeen, some of whom, like Deutsche Lufthansa, which appeared in 1955, became prominent surprisingly quickly, to say nothing of Seaboard and Western, a company handling freight exclusively.

Let us look at the results of the first half of 1960.

Companies (parentheses indicate year North Atlantic service opened)	North Atlantic passengers January—June 1960
Pan American World Airways PAA	159,759
Trans World Airlines TWA	107,712
British Overseas Airways Corp. BOAC	73,197
Air France	52,535
Scandinavian Airlines System SAS	44,400
KLM Royal Dutch Airlines	43,665
Deutsche Lufthansa DLH (since 1955)	37,592
Trans-Canada Airlines TCA	32,987
Sabena	29,357
Alitalia (since 1957, as LAI since 1951)	20,105
Swissair (since 1949)	19,043
Canadian Pacific Air Lines CPAL (since 1956)	13,396
El Al Israel Airlines (since 1951)	12,453
Irish International Airlines (since 1958)	9,977
Qantas (since 1958)	5,052
Iberia (since 1954)	4,117
Air-India (since 1960)	2,361
Total	664,708
U.S. share (PAA + TWA)	267,471 (40%)

As far as their share of the North Atlantic total is concerned, PAA and TWA were barely able to catch up with 1959 in the first half of 1960. It may be safely assumed that they will have been even less successful in the second half of the year, because in the course of 1960 their competitors took delivery of jet aircraft which they had previously ordered.

Leaving room for error, the following firms operating over the North Atlantic route obtained (up to the end of 1960) all the long-range aircraft they had ordered from Boeing and Douglas: Air France took 17 Boeing 707-328s and ordered 3 more; BOAC (15 Boeing 707-436s, final delivery January 1961); Sabena (5 Boeing 707-329s); SAS (7 DC-8/30s); Swissair (3 DC-8/30s). In the case of other firms a few deliveries have still to be made: KLM has obtained 7 DC-8/30s and expects to get 5 DC-8/50s in 1961; Air India obtained 3 out of 4 707-437s; Alitalia 4 out of 10 DC-8/40s; Deutsche Lufthansa 4 out of 5 Boeing 707s, TCA at least 4 out of 11 DC-8/40s, while CPAL, El Al and Iberia are expecting to obtain their jets in 1961.

What is more, the shrinking American share of total traffic is by no means limited to the North Atlantic route exclusively, but is felt throughout the international passenger industry. The 21st edition of the annual publication of the Air Transport Association of America (ATA), "Facts and Figures About Air Transportation, 1960," anxiously comments: "U.S. international airlines established new traffic records in 1959 but faced increasingly stiff competition from foreign airlines serving the U.S.—foreign market... Most passengers travelling between the U.S. and foreign countries are U.S. citizens. In 1959 the percentage of U.S. citizens to total travellers was 64.2%. Yet foreign airlines serving the U.S. have increased their share of this market from 14.6% in 1950 to 43.2% in 1959. Conversely, the U.S. flag airlines' share dropped from 85.4% to 56.8% in the same period."

*

Incidentally, the Americans are not the only people to make such calculations of percentages. The annual report of Deutsche Lufthansa for 1959 sadly remarks that the company's share in international air traffic does not in any way correspond to the Federal Republic's share in world trade.

Share in world trade (according to Deutsche Lufthansa sources)		Share of international air traffic
USA	16%	33%
Great Britain	10%	12%
France	5%	7%
Scandinavia	5%	5%
Holland	4%	7%
Italy	3%	2%
Switzerland	2%	3%
German Federal Republic	9%	2%

More differences than agreements

After what has been said here, it is not surprising that air transport companies are eying each other with suspicion, and that responsible authorities in the various countries are thinking twice about signing new air transport agreements or extending existing ones.

In itself, this mutual suspicion is nothing new. It is enough to recall the attacks made by the U.S. Senate Committee on Interstate and For-

eign Commerce, in the spring of 1956 against the "sellout" of the American air transport market to European firms. The Committee's report teems with expressions like "entrapment" or with phrases like "bargaining away too frivolously the value of the U.S. market" and so on. At that time the American senators were highly alarmed by the large-scale granting of landing rights to Deutsche Lufthansa, and today the Americans—and others as well—see every foreign aircraft as a bird of prey.

Without making any claim to completeness, let us examine certain negotiations over air traffic agreements which took place in 1960, and then broke down.

The "casualty list" begins in January with the fruitless American-Dutch negotiations over KLM's landing rights at Los Angeles. After these rights were refused, KLM President Aler remarked: "Apparently American air traffic policy is being guided by protectionist principles, under pressure from U.S. air transport companies."

In February the British and Americans engaged in an equally acrimonious and unsuccessful dispute over the revision of the Bermuda Agreement of 1946, and in spite of a six-week prolongation of these talks in May 1960 at Washington, there was no agreement over a total of eleven disputed points, including landing rights for Northwest Airlines in Hong Kong, extension of TWA's route to Zurich via London and Frankfurt, BOAC services from the Caribbean to the U.S. and from San Francisco to Honolulu and Sidney so as to complete BOAC's second world circuit. The British magazine *Flight* has given the title "The Poker Game" to a report on the Anglo-American negotiations which were carried on in the shadow of the old Pan Am-BOAC rivalry.

In contrast one might cite a U.S.—Mexican agreement in August 1960 which passed off fairly smoothly, and another which was also signed in August after protracted discussion between the United States and Italy over the fifth "freedom of the air" for Alitalia's traffic between Canada and the West coast of the U.S., with corresponding rights for the Americans in Genoa and Turin.

However, there were wrangles in September 1960 at Copenhagen, where the American delegation's aim of curtailing SAS North Atlantic traffic encountered embittered resistance from the Scandinavians. Stuart G. Tipton, President of ATA, urgently requested the U.S. delegation (before their departure for Europe) to stand fast, and to cut SAS's capacity for New York and Los Angeles by half during the summer season, and by two thirds during the off season. The American attitude towards Scandinavia would be maintained, he said, in later discussions with other "contract breakers." After these "home truths" the opposing sides parted unreconciled.

Difficulties are brewing for the Scandinavians in another quarter. After SAS's entry into the jet market the Federal Republic moved to limit landing rights for the Scandinavians, apparently with the subsidiary aim of shaking off the remaining handicaps from which Lufthansa has suffered since the immediate postwar period. A conference held in Copenhagen in October proved to be a dismal failure after 24 hours had elapsed. In a bulletin, Lufthansa expressed its regrets that SAS, with which it had direct contact, demanded preferential treatment, though it had nothing to offer in return. For example, it wanted traffic rights for its Far Eastern routes before knowing the outcome of the German-Thai negotiations, which were made even more difficult by the participation of SAS in Thai Airways.

In the U.S.-Indian negotiations, which dragged on for months, one harsh blow was struck after another, and a final effort at New Delhi in October caused the discussions to be terminated without result.

The series of breakdowns in 1960 concluded with the *sine die* postponement of the American-Filipino talks at Manila, in which Philippine Air Lines request for landing rights at Tokyo for its planned Manila–Tokyo–Honolulu–San Francisco route was turned down because the competing American carriers Northwest Airlines and Pan Am energetically resisted the "watering down" of Pacific traffic. They demanded that the Filipino carrier demonstrate the need for operations over this route. The toughness of these negotiations is shown by the fact that the Filipinos have threatened, if their wishes are not met, to cancel their intended order for two Douglas DC-8(50) long-range jet aircraft.

Although anything but complete, this list gives an indication of the general situation.

No way out?

In an article which appeared in mid-November 1960, IATA attempted to account for the breakdown of the American-Scandinavian negotiations and came to the sobering conclusion that differences over mutual traffic rights of air transport companies could not be reconciled by bilateral national agreements of the current type. The entire system of bilateral agreements had a basic flaw, because it rested on principles which had validity only for multilateral traffic, and were thus suited only to multilateral agreements.

This standpoint cannot be rejected summarily. Without going into the legal details, an attempt can be made to give a brief survey of developments.

At the Chicago conference of 1944 which led to the creation of ICAO, two drafts for multilateral agreements were submitted to the participating States, in addition to the ICAO statutes. They were designed to guarantee the complete freedom of air transport—in the sense of the freedom of the high seas.

In the resulting transit agreement the first and second freedoms of air transport were defined: the right to peaceful overflight without landing, and the right to land for non-commercial purposes (for fuelling, etc.) There was no ratification of the so-called transport agreement, the draft of which aimed to guarantee to the air traffic of all member States the following unlimited rights: The right to take passengers, mail, and cargo from the country whose nationality the aircraft possesses to the country of destination (third freedom); the right to transport passengers, mail and cargo from the country of destination back to the country whose nationality the aircraft possesses (fourth freedom); the right to transport passengers, mail and cargo from the territory of any one ICAO signatory state into the territory of another (fifth freedom).

Understandably, the States which agreed on the unlimited freedom of the air were those which had only a small hinterland and a small population, while many of the great powers even then had second thoughts, and preferred a stricter regulation of future international air traffic.

If these "freedoms of the air" bore no fruit of their own, they nevertheless sent out shoots. For air-faring states have had to accept bilateral air transport agreements if they wish to regulate their air traffic.

The first bilateral agreement, which the American and British concluded in Bermuda in 1946 and which served as the prototype for countless further agreements, recognized the IATA fare structure, established a certain number of routes which the air transport companies of the two states might fly, and finally regulated the "capacity" of these routes.

The Bermuda Agreement (or rather, the appendix to this agreement—for the essential part of international agreements is always found in the appendices!) states: "The two contracting parties agree, that . . . services provided by a designated air carrier shall retain as their primary objective the provision of capacity adequate to the country of which such air carrier is a national and the country of ultimate destination of the traffic (third and fourth freedoms: Ed.) . . . The right to embark or disembark on such services international traffic destined for and coming from third countries (fifth freedom: Ed.) . . . shall be applied in accordance with the general principles of orderly development (of air traffic; Ed.) . . . and shall be subject to the general principle that capacity should be related:

a) to traffic requirements between the country of origin and the countries of destination;
b) to the requirements of through airline operation; and
c) to the traffic requirements of the area through which the airline passes after taking account of local and regional services."

Expressed more simply, this means: in determining transport capacity it is essentially a matter of considering the traffic requirements between the two signatory states (third and fourth freedoms); the traffic requirements of third-party states are of secondary importance (fifth freedom).

It is precisely in this regulation that one source of the difficulties affecting bilateral treaties lies. The Americans reproach SAS for the fact that only 47% of its North Atlantic flights are derived from the third and fourth freedoms, while 53% touches the fifth freedom. A passenger who is flown by SAS over the New York–Copenhagen–Hamburg route must by "law" be left to an American air transport company, for he is the "object" of the third freedom of the air for the Americans in their agreement with the Federal German Republic.

Not at all, say the Scandinavians. Between New York and Copenhagen this passenger would come under their fourth freedom with the USA, and between Copenhagen and Hamburg under the third freedom of the air of the German–Scandinavian air traffic agreement.

*

This brings us to the end, but unfortunately not to the "destination," of this trip through air traffic negotiations. What is going to happen? It is hard to say. All ICAO states are still calling for multilateral agreements. However, it is a well-known fact that cordiality evaporates over questions of hard cash. ⟷

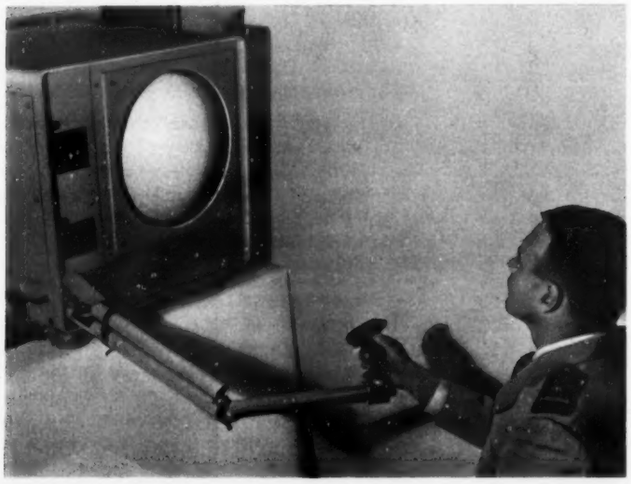
Electronics in Aviation and Industry

What's New in Electronics?

■ **Daito Corporation, Norwood, New Jersey,** has supplied Visual Flight Simulator attachments to Eastern Air Lines, United Air Lines, the U.S. Air Force, the U.S. Navy and the FAA Experimental Test Center. The attachment is a closed-circuit television device which can be synchronized to existing electronic flight simulators to give a visual, live pattern of approach and runway lights, as seen by a pilot during the final stages of an approach and landing under conditions of less than 300 ft ceiling and half-mile visibility. An approach and runway lighting pattern is fitted on an endless moving belt and is viewed by a closed-circuit television camera. The resulting picture is then displayed on a screen located in front of the simulator windscreen. The camera is synchronized electrically to the computer of the flight simulator. When the pilot flies the simulator, the signals generated by the computer control the attitude of the camera, together with the relative speed of the belt travel. The camera can move about the roll, pitch and heading axes and can also be raised and lowered to simulate altitude changes, and displaced from the centre line of the runway. The picture presented to the pilot, because of the variable camera viewpoint, gives the impression that the aircraft is moving relative to the approach and runway lighting patterns.

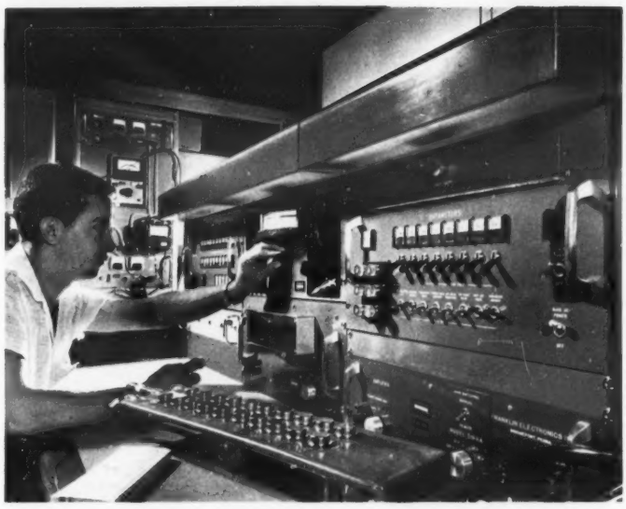
Apart from training in the vital transition phase when the pilot must transfer his attention from the flight instruments and continue the landing by visual aids, the simulator attachment extends the exercise to the point where the aircraft touches down on the runway and comes to a full stop. With many flight simulators, the exercise ceases when the pilot has completed the instrument part of the approach, and there is no indication that the aircraft is correctly positioned in space and is maintaining the correct heading, height and airspeed to complete a satisfactory landing. A synthetic training aid which prolongs the exercise to the point where the aircraft comes to a halt on the runway, is invaluable to the pilot, as each approach presents the problem of deciding whether the landing can be safely completed or whether the missed approach procedure should be initiated.

■ **Radiation Inc, Orlando, Fla.,** has developed the AN/ARW-T2 Ground Pilot Trainer for supply to the U.S. Navy. The Navy utilizes the Trainers to train pilots in the operational aspects of the *Bullpup* air-to-ground weapon system. Training is accomplished by simulating the missile's flight characteristics on the face of a cathode ray tube display. These motions are controlled in the same manner as that used to control the missile in actual operation. Missile characteristics which are not under the control of the pilot-trainee are electronically generated within the Trainer. To provide further realism to the Bullpup training programme, the simulators are equipped with read-out devices which automatically display the miss-distance at the conclusion of each exercise.



■ **General Electric Co, Syracuse, New York.** The photograph shows the U.S. Army's improved *Nike-Hercules* system installation at the White Sands Missile Range, New Mexico. The large radome houses the General Electric-built high power acquisition radar (HIPAR) while the tracking radars are installed in the three small radomes. The tracking radars are built by *Western Electric Company*, prime contractor for the *Nike-Hercules* system. The acquisition and tracking capability of the system was recently demonstrated in a trial in which a *Hercules* missile was launched and successfully intercepted another *Hercules*.

■ **Rohde und Schwarz, Munich,** has announced a vibration frequency analyzer which can be used to measure frequency speeds and amplitudes in solid bodies. The machine can measure vibrations in a range extending from 10 to 12,000 c/s and can be used for the detection of vibration sources in machinery, turbines, vehicles, ships, aircraft and buildings. The directional selectivity of the acceleration pickup in the device makes possible a separate measurement of the amplitude components. By the attachment of equipment such as oscillographs, recorders, band filters and tape recorders, the machine can be made into a universal measurement tool.



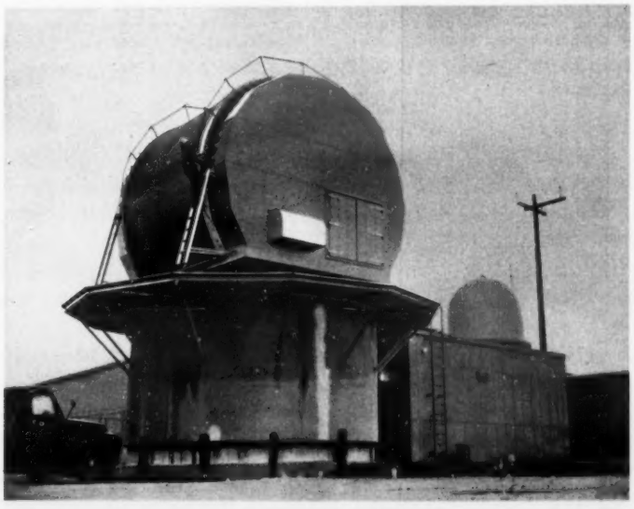
■ **Delco Radio Division, General Motors Corporation, Kokomo, Ind.,** has established and is operating a reliability programme for power transistors which are to be used in the *Minuteman* missile. A contract has been made with *Autonetics* division of *North American Aviation, Inc.*, associate prime contractor responsible for the inertial guidance and flight control systems for the *Minuteman*. The contract provides for the exhaustive testing of some 75,000 Delco power transistors. The aim of the programme is to produce powe transistors which will achieve a success rate of 99.997 percent. This means tha a single transistor can be expected to have a lifetime of 40,000 years. To carry out this test programme, special equipment has been developed at Delco. This includes large high-temperature ovens capable of testing up to 40,000 transistors at one time, a high-altitude chamber capable of testing transistors under operating conditions at a simulated altitude of 160,000 ft at 100° Fahrenheit below zero, a salt water test device and a centrifuge capable of subjecting transistors to 120 G forces. Illustrated here is a device which checks and records eight transistor parameters and records the information on IBM cards. A rack of 20 transistors can be fully tested and the information for each recorded on its own IBM card in three minutes.

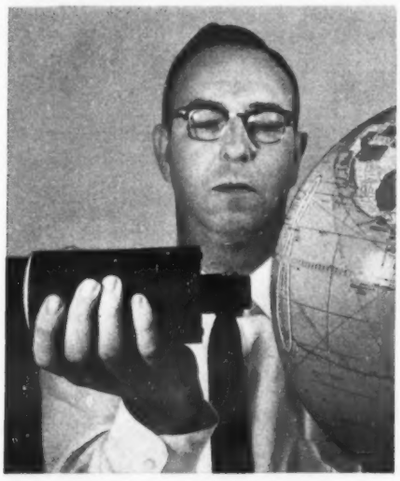
■ **Brush Crystal Co., Southampton, England,** is producing a new material known as PZT ceramic, under an exclusive licence in the United Kingdom. This is a synthetic material, developed by the Clevite Corporation of America, which possesses piezoelectric properties. The new ceramic has been employed in the construction of a device which may have a revolutionary effect on the design of future petrol engines. The device, termed a "spark pump," utilizes the piezoelectric properties of the PZT ceramic to provide the high voltage required for the engine ignition system. This piezoelectric effect is displayed by certain crystalline substances such as quartz. When pressure is applied to such a material, equal and opposite electrical charges are generated on its opposite sides. The potential of these charges is proportional to the extent of the pressure applied. The spark pump contains two small elements of the ceramic, each about a third of an inch in diameter, and a timing switch which directs the pulse of high tension electrical energy to the spark plug at the correct instant. When a load is applied to the PZT elements in the pump, the piezoelectric effect generates a potential of approximately 20kV. Pressure is exerted on the elements by a lever attached to either the crankshaft or camshaft of the engine. The spark pump is simple in construction and compact in size. A particular advantage lies in the fact that it produces a constant voltage at all engine speeds, the power output being dependent on mechanical pressure and not upon rotational speed. The life of the ceramic elements has not yet been assessed through operational use, but it is known to exceed 500 hours running time at an engine speed of 3,600 r.p.m. The elements can be easily replaced in the pump when necessary.

The Clinton Engine Corporation of America is the first company to adopt this new ignition system, and a Clinton industrial engine, equipped with a spark pump, was exhibited at the Royal Smithfield Show in London in December.

■ **Infrared Industries, Waltham, Mass.,** has recently made an announcement of the development of a new communications system, which depends on the modulation of a beam of infrared light. The transmitter/receiver is contained in a lightweight case similar in size and shape to a miniature motion picture camera and has a range of several hundred yards. The apparatus works equally well in darkness or in bright sunlight. Power is supplied by small batteries which can be easily replaced. To transmit, the operator speaks into a microphone which feeds an amplifier/modulator in the light beam supply circuit. The resulting modulated beam is focussed optically by a series of lenses and then directed toward the receiver. In the receiver a photoelectric cell converts the impulses in the beam and feeds the signal into a conventional amplifier which is connected to a loudspeaker or headset. Ship-to-shore communications are an obvious application of this new short-range system.

■ **General Electric Company, Syracuse, N.Y.,** recently announced that it has completed the last of the scheduled radio guidance sites for the *Atlas* missile. Much of the ground-based equipment for the *Atlas* radio-command guidance system is installed in a blockhouse called the Launch Operations Building. Alongside this building, a 13 ton precision tracking radar stands 34 ft high. The radome itself is 20 ft high and rests on a pedestal of nearly 400 tons of concrete. Also, outside the operations building, the guidance system has two rate-measuring antennas. These rate antennas provide the velocity and acceleration information to the guidance system. This data, together with the tracking information from the large precision tracking radar, is transmitted to a computer which determines whether any correction commands need be sent to the radio guidance equipment aboard the missile. At the precise moment that the correct velocity and trajectory have been achieved to ensure that the missile strikes the target, the guidance system sends a signal from the ground-based equipment to the missile to cut off its engines. This technique of tracking with a precision radar and determining the missile's velocity and acceleration with a precise rate-measuring system has given the *Atlas* radio-command guidance system a high degree of accuracy and reliability. A further advantage is that it requires very few personnel. Only one guidance control officer, a radar specialist and a computer specialist are required as part of the SAC guidance operations crew, and only the guidance control officer is required to take part in the actual countdown of a missile. After launch the tracking antenna automatically turns to line-up on the missile in flight. This antenna is rotated simply by a change in voltage sent to the servo-drive system by the tracking receiver. Once the launch button is pressed, the guidance of the *Atlas* is completely automatic. The illustrations show the precision tracking radar at the side of the launch operations blockhouse, with the smaller radome containing the antenna for the rate measuring system in the background. In the second illustration, the radar specialist is seated at the maintenance panel on the left, with the guidance control officer at the guidance console, right.



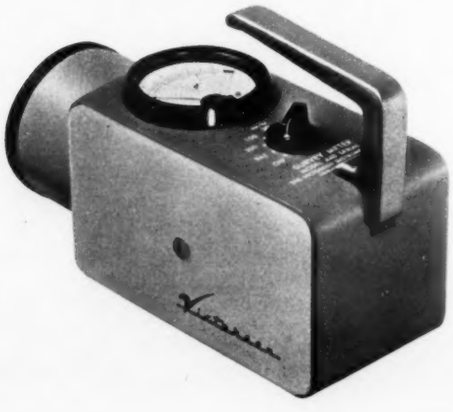


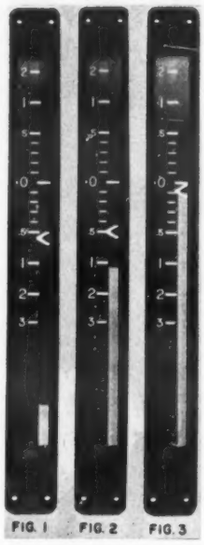
■ **International Telephone and Telegraph Corporation, San Fernando, Calif.,** has developed a small electronic device termed an attitude sensor which can position orbiting satellites. The device has no rotating parts or bearings and requires less electric power than a miniature flashlight bulb. It is designed to keep satellites properly oriented in reference to the centre of the earth once they achieve the correct orbit. Signals from the sensor unit are transmitted to special control equipment on the satellite which then positions the vehicle and maintains it in control. Power is supplied by solar cells or normal battery units. The correct positioning of the satellite begins when the image of the earth is picked up by the optical lens of the sensor. Portions of this image are deflected by four small mirrors mounted on leaf-type vibrating springs. A high frequency is applied to these springs, which tilts the mirrors in synchronism, causing the edge image of the earth to be swept across the detectors. Signals from the detectors are compared, and the resulting signal is transmitted to the satellite control equipment. The absence of rotating parts gives the device a life expectancy of approximately five years.

■ **Raytheon International, Waltham, Mass.,** has announced the development of a cathode ray tube which can remember and visually indicate signals up to two hours after they have been received. Within its memory span, the tube, designated CK1362, can present its remembered signals repeatedly up to a total visual read-out time of one minute. The signal traces can be erased when necessary by the application of high infrared energy. The signals are stored in the phosphor of the tube screen and are released in the form of light when small doses of infrared energy stimulate the phosphor coating.

The tube is used in the true motion indicator of the Raytheon Mariners Pathfinder radar. In this application the tube shows the true course and movement of its own ship and all objects within the range of the radar. When low-level infrared energy is applied to the screen, moving objects and the direction of their movement are identified by short visible trails on the screen. Other applications of this tube are in oscilloscopes which can compare signals visually, and in airport ground traffic control radars where brief, frequent displays and fast erasures are necessary.

■ **Victoreen Instrument Company, Cleveland, Ohio,** has developed a portable survey meter capable of detecting extremely low levels of radiation. It has been designed for use around radar and microwave installations and X-ray laboratories. The meter will detect and measure radiation of less than one milliroentgen an hour by picking up currents generated as the radiation enters an air ionization chamber through an extremely thin window. An important application of the meter is the detection of radiation leakage at sites where radiation-producing material is in use. This is particularly important in the protection of personnel, as exposure to low level radiation over a period of weeks or months can result in an accumulation above allowable limits. In the course of operational trials, the meter was exposed to extreme environmental conditions at the Thule, Greenland, Ballistic Missile Early Warning System base, where large radar antennas provide a source of radiation.





■ **Lear, Inc., Santa Monica, Calif.,** has recently delivered a new absolute altitude/ instantaneous vertical speed indicator to the Flight Control Laboratory, Wright Air Development Division. The instrument has been developed under the guidance of the Laboratory, and evaluation trials will now be carried out in an all-weather landing programme which is being conducted jointly by WADD and the Federal Aviation Agency.

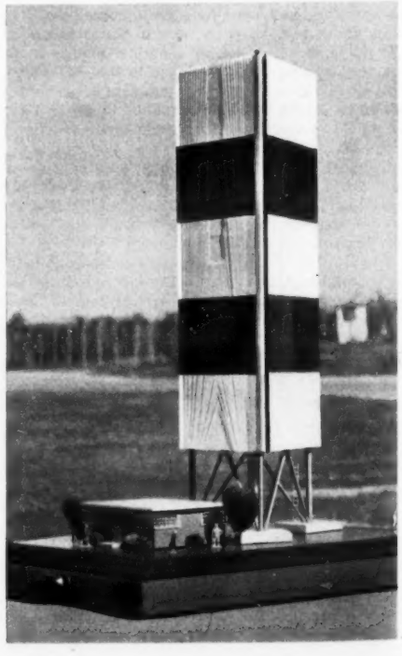
The instrument is one inch wide and ten inches high at the face and provides a vertical display of altitude and vertical speed on a combined scale. The three illustrations show successive stages in the course of a normal landing approach. In *Fig. 1* as the aircraft descends below 200 ft altitude, a bright orange thermometer-type tape appears at the bottom of the display and moves upward to the zero or ground reading. The V-shaped pointer at the right of the scale indicates a rate of descent of 600 ft per minute. In *Fig. 2* the pilot has reduced the rate of descent to 500 ft per minute and the tape indicates that the aircraft is nearing the ground. When the altitude reaches the pointer, the pilot simply lessens his rate of descent to coincide with the altitude tape's movement towards zero. Since rate of closure is directly associated with change in vertical speed, keeping the altitude tape and the vertical speed pointer aligned ensures the desired asymtotic flare-out. In *Fig. 3* the tape and pointer are shown prior to touch-down, with the aircraft descending at 80 ft per minute.

When vertical speed indications exceed 3,000 ft per minute in either climb or dive, the pointer remains fixed at the end of the scale, and a moving tape behind a window reels off vertical speed rates in thousands of feet. Under 3,000 ft per minute, the pointer itself moves against a fixed scale.

■ **The W.L. Maxson Corporation, New York, N.Y.,** is working in conjunction with the Federal Aviation Agency's National Aviation Facilities Experimental Center, on the design and construction of the AHSR-1 height finding radar. The equipment is now in the process of installation at NAFEC. It consists of three major items: an antenna system, an electronics building and an illuminating radar. The latter can be the same radar that is used to give the air traffic controller distance and direction information. The use of the same reflected signal for the height finding radar eliminates the need for a separate transmitter.

The heart of the AHSR-1 system is the antenna. This consists of three panels, each measuring 135 ft by 43 ft and mounted on a triangular tower, 160 feet in height. Each panel contains over thirty miles of rectangular waveguide tubing. There are no moving parts in the antenna system, and once it is erected and adjusted it should work for many years with the minimum of maintenance.

Signals reflected from the target aircraft enter the horizontal sections of waveguide. As the signal travels along these guides, samples are taken off through the vertical guides, each of which is connected to a receiver. In one vertical guide, and one only, will the samples be in phase, thus enabling the controller to determine the elevation angle of the aircraft. The slant range to the target is known from the illuminating radar, so that the aircraft altitude can be determined by simple trigonometry.



What Should the Equipment of a VTOL Strike Aircraft Weigh?

By Luigi Vercelli and Riccardo Bignamini,
Fiat Divisione Aviazione, Turin

The increasingly high performance and the more stringent demands made on tactical aircraft are causing design offices ever greater difficulty in the selection and installation of airborne systems. Moreover, the various equipment parts are growing steadily more complicated and numerous and are claiming a larger and larger share of the aircraft's equipped weight. This unavoidable tendency towards complication is not adequately compensated for by progress made in miniaturization techniques.

In the case of a VTOL aircraft, additional complications are involved, and these in their turn require extra pieces of equipment. It is therefore not surprising that this problem is giving design engineers severe headaches.

The overall weight of the equipment carried, multiplied by the characteristic growth factor for the aircraft under consideration, is of decisive importance in estimating the aircraft take-off weight, which must not exceed the maximum thrust of the available lift/propulsive powerplant. An exact forecast of equipment weight is therefore highly important in any VTOL design.

On the other hand, such estimates are difficult, since the equipments required cannot simply be ordered from types already available on the market, but are in most cases special developments for which the weight data must be assumed. Designers of VTOL aircraft are forced to aim at extreme lightness of construction, and binding weight specifications must therefore also be laid down for the equipment, naturally taking account of the purpose for which it is to be used and the current state of the art.

Due consideration being given to these limitations, the vital equipment for a VTOL military jet aircraft is listed below. This list is followed by an estimate of the total equipment weight, in order to furnish a conclusion as to the feasibility of the project.

Roughly speaking, the necessary equipment can be divided into three categories, depending on whether it is required for pilotage and navigation, the performance of military missions, or the safety and comfort of the pilot.

1. *Pilotage and navigation systems*
   - 1.1 Flight and engine instrumentation;
   - 1.2 Navigation equipment for visual and blind flying;
   - 1.3 Instrument approach and blind landing systems;
   - 1.4 Communications equipment;
   - 1.5 Autostabilization equipment.

2. *Armament; aiming, fire control and missile guidance systems; reconnaissance equipment*

3. *Safety equipment and installations to lighten the pilot's task*
   - 3.1 Oxygen apparatus;
   - 3.2 Pressurized air and air conditioning system;
   - 3.3 De-icers, defrosters and windscreen wipers;
   - 3.4 Ejection seats;
   - 3.5 Air intake de-icers;
   - 3.6 Fire warning and fire extinguishing equipment.

*

The following are a few guiding lines for the choice of these pieces of equipment.

The information provided by the flight instrumentation must be supplied to the pilot in integrated form, to enable him to judge his flight situation at a glance. This requires a gyro centre or a gyro-stabilized platform in conjunction with the air data centre and the compass system, plus one or two combined instruments to indicate vertical and horizontal attitude. This installation supplies information to a series of further aircraft systems, in particular the autopilot, navigation system, bomb aiming system, fire control and weapon guidance systems.

The navigation system must work independently of ground aids. It will probably be composed of two sections: one (doppler radar or inertial navigation system) will give highly accurate fixes, while the other (dead reckoning computer) will serve as an emergency system to give approximate indications of position on the basis of true airspeed, heading and estimated wind data.

For flight safety in poor weather an obstacle warning radar is indispensable, since the aircraft must often fly only a thousand feet or so above the ground. If possible, this radar should be capable of connection to the autopilot for automatic corrections of course and attitude.

It is difficult to lay down guiding principles for instrument approach and blind landing. A number of experts advocate the adoption of parabolic approach paths to be maintained with the aid of supplementary automatic devices attached to the autopilot; this would substantially reduce the time required for the complicated approach manœuvre. It is, however, prudent to allow for a fully automatic approach and landing system when calculating equipment weights. Little weight would be saved by dispensing with the automatic system, as the pilot would still have to have adequate instrumentation for emergency and monitoring purposes. In any case, the autostabilizer and autopilot for cruising should not differ significantly from the equipment used in conventional aircraft.

Communication equipment is in a class by itself. Where an aircraft has to make low-level penetrations far into enemy territory, conventional UHF radio is of no use. It must be supplemented by HF or MF communication equipment requiring a special antenna.

The items of equipment in *category 2* include not only weapons of all kinds, but also reconnaissance equipment for day and night-time operations and flight in bad weather with nil visibility. It is not, however, possible for an aircraft to carry all varieties of armament and all types of reconnaissance equipment at one and the same time. A number of combinations (military loads) must be provided, and these must be readily interchangeable to equip the aircraft for a variety of missions. This, of course, leads to an increase in the structural weight of the airframe, as special pylons, electric cables and control systems are required, and these are permanently installed in the aircraft. An advance estimate of the weights of individual equipment parts is therefore no simple matter; the most that can be done is to calculate an overall value based on experience.

The equipment required to lighten the pilot's task and ensure his personal safety in an emergency comprises (apart from classical items such as oxygen apparatus, pressurized air, air conditioning, de-icing and defrosting systems) one or more ejection seats, which must be capable of operating at speeds from zero to high supersonic, and at heights between zero and the stratosphere. Last, but by no means least, provision must be made for good all-round visibility—even in driving rain or snow—a feature which is difficult to incorporate in a VTOL strike aircraft.

It is also advisable to provide a comprehensive fire warning and fire extinguishing system. No matter what the powerplant chosen—whether several fully or partially deflectable turbojets or turbojets with thrust deflection mechanisms—the propulsive system of a VTOL aircraft is invariably far more complicated than that of a conventional aircraft, and the danger of fire is increased accordingly.

The accompanying diagram gives an idea of the great number and variety of the problems of equipping a VTOL aircraft for ground support and tactical reconnaissance. The following table gives a breakdown of weights.

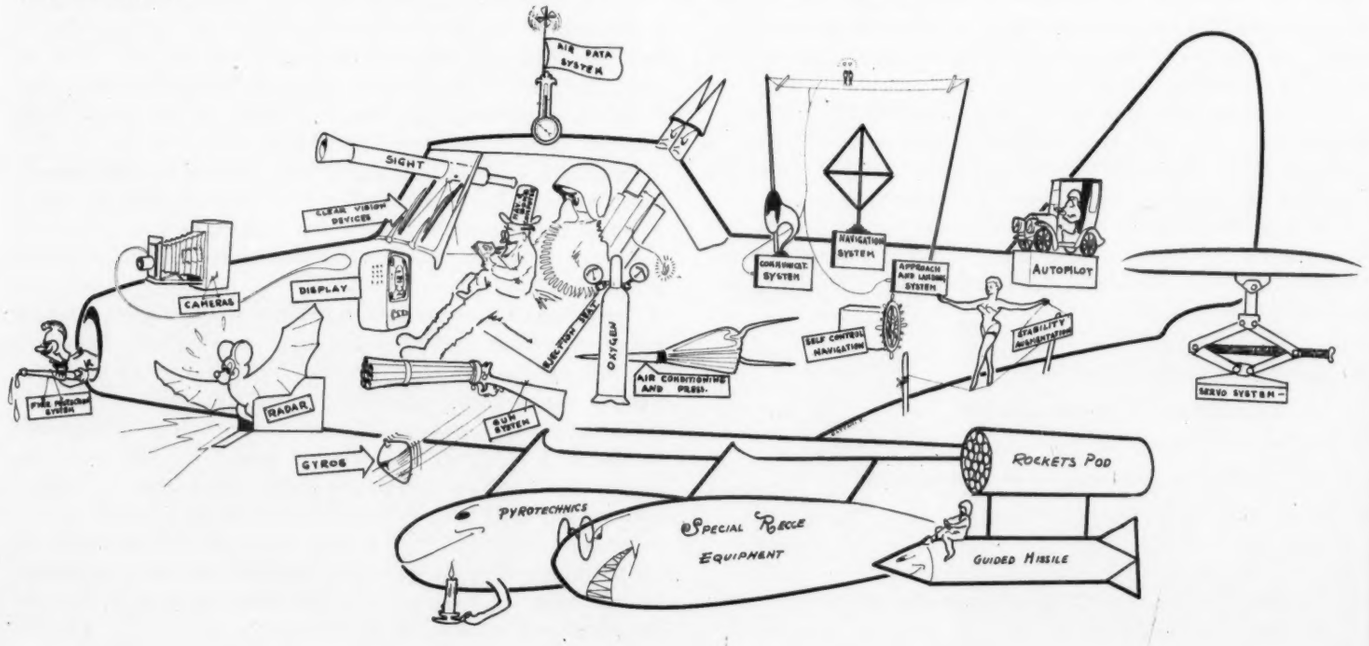
Systems and instruments for the navigation and pilotage of the aircraft	1,050 lb
Military load, bomb aiming device, fire control and missile guidance systems, reconnaissance equipment, all in interchangeable units, plus fixed fittings for installation	1,450 lb
Safety equipment and equipment to lighten the pilot's task	500 lb
Total weight of equipment	3,000 lb

The meaning of these figures is clear to the expert. It is understandable that design engineers must make every effort to combat the tendencies towards increased weight in the equipment of VTOL aircraft. For even though the feasibility of a VTOL project appears more or less proven on the basis of the principles discussed in the present article, and there will undoubtedly be further progress in engine building in coming years, it is to be feared that the growth potential which should be built into every new design will remain seriously limited in the case of the VTOL aircraft.

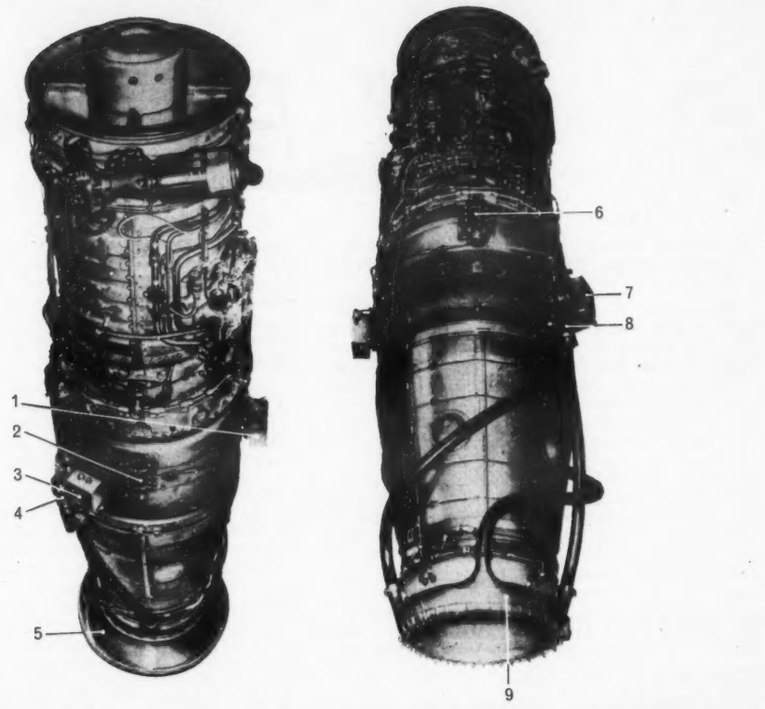
If, however, one is satisfied with a STOL strike aircraft for high subsonic speeds, then the weight of equipment can be slightly less. Weight can be saved in particular in the flight instrumentation, the instrument and blind landing systems, the autostabilizers and autopilot.

In addition, the weight saved on the control system would be considerable, as a VTOL aircraft requires an additional jet control system which can be dispensed with in the case of STOL aircraft.

The standard instrumentation of a single-seat combat aircraft. From left to right, top to bottom, nothing but nstruments, equipment, black boxes, not to mention the pilot himself... All this and VTO too?



SNECMA Contributions to VTOL



This SNECMA jet engine for vertical flight powered the *Atar Volant* and the C.450 coleopter. The jet deflection nozzle enabled the thrust vector to be deflected in any direction, giving the aircraft two-dimensional control. Rolling movements about the longitudinal axis were achieved by blowing pressurized air from special nozzles at an adequate distance from the central axis. The SNECMA jet deflection mechanism shown here can be fitted to any jet engine. 1–actuator mechanism; 2–valve for roll control; 3–actuator mechanism; 4–valve for yaw control; 5–thrust control devi ce; 6–valve for roll control; 7–actuator mechanism; 8–valve for pitch control; 9–jet deflection nozzle.

The Société Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA) was one of the first large companies to undertake a systematic study of the problems involved in vertical landing and take-off.

It is not intended to give a historical review of the efforts made by this large French company in this field. It suffices to note that the work started in 1952 with theoretical studies, which indicated the general principles which were to be followed, and to mention the early experimental models and subsequent developments.

The major tests were mainly concerned with the problems of control and stabilization at hovering speeds. In this respect SNECMA was able to draw upon the results previously obtained by its research engines in the control of high-speed, high-temperature gas flows.

These data were used in the development of the flow-controllable jet pipes designed for the vertical take-off aircraft which SNECMA has been developing. The jet pipes constitute one of the vital control elements during low-speed flight. In passing, it is interesting to note that the directional control of the jet is achieved by means of supplementary air jets and not by the presence of mechanical devices in the hot gas stream.

The jet controls are connected to an auto-stabilization device which senses angular displacements and applies the corrections necessary. The control drive was designed so that the high degree of stability provided by the system did not affect the flight handling characteristics of the aircraft.

The efficiency of the methods adopted for stabilization and jet control was extensively demonstrated by the performance of the remote-controlled *Atar Volant C.400 P1* (1955-1956) on a gyro test bench and on a safety rig at Villaroche. This was later confirmed in piloted flight, first with the *Atar Volant C.400 P2* in 1957, which was demonstrated to the public during the Paris Salon at Le Bourget during the same year, and later by the tests carried out on the C.450 coleopter (1958-1959).

The tests of the coleopter were unfortunately interrupted by an accident during the summer of 1959. The SNECMA system of vertical flight control, which had already undergone lengthy and searching proving, was not, however, a contributory factor.

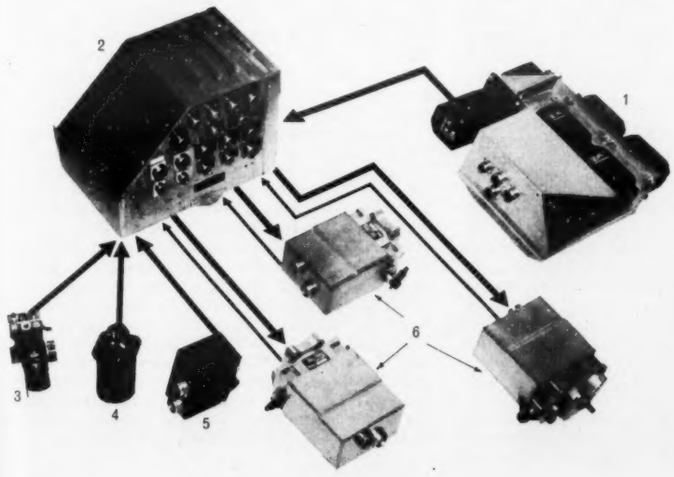
The configuration of the *Atar Volant* and of the C.450 coleopter was evidence of SNECMA's choice of the "tail sitter" formula for vertical flight. This configuration does not require special propulsion systems or pivoting mountings for the engines and also offers no limitation to the shape of the airframe. The adoption of the annular wing for the C.450 enables it to be developed as the shroud for a ramjet, thus combining the use of this type of motive power for lift, with a high speed capability, in the region of Mach 3.

This brief outline of the work already carried out by SNECMA indicates the many possibilities that exist for the future. The techniques of jet efflux control employed by SNECMA are applicable to any jet engine, to make it capable of vertical flight and adaptable to aircraft of any aerodynamic formula. In this connection it is interesting to mention the development work carried out under the agreement between SNECMA and Pratt & Whitney on the by-pass engines of the American company. This work is directed toward the development of engines specifically designed for vertical flight, which are capable of providing the high thrust required for take-off, landing and special missions and at the same time retain a low specific consumption in the cruise regime.

The experience gained from the various special aircraft constructed by SNECMA has led to the development of a "*stabilization control unit*" which is adaptable to all types of STOL and VTOL aircraft. This unit uses a gas bleed from the engine to supply the stabilization and control forces around the three axes. The basic development work, followed by more than 500 tests on the test bench and in flight, indicates that the unit is ideally suitable for series production.

During its work on vertical flight, SNECMA has also developed the special *Lumisol* altimeters. These instruments operate by means of light signals and simplify the landing manœuvre by the accurate indication of height at low altitudes, or by indication of a preselected altitude. As they are of small size they can be adapted to all types of aircraft.

In conclusion, mention should be made of the experiments carried out by SNECMA on the ground erosion effect of the hot gas efflux. This particular feature of VTOL operation is one of outstanding importance.



SNECMA stabilizer system. This is suitable for STOL aircraft and for VTOL aircraft of both the flat riser and tail sitter types. Engine bleed air is used for stabilization and control by means of mechanical or pneumatic jet deflection, spoiler nozzles etc. The stabilizer can also be used with any other control system for low flight speeds. It consists of the following compact, lightweight parts: 1–sensor unit; 2–transistorized amplifier unit; 3–trim control; 4–control knob; 5–flight data transformer; 6–actuator mechanisms. The control system receives commands from both the stabilization unit and the pilot.

Book Reviews

The Smirnoff Story. — By Anne Robertson Coupar. Jarrolds, London, 1960 (English; 272 pages; price 25 shillings).

The author, an experienced feature writer and reporter, here gives an entertaining account of the life story of a Russian World War I pilot, who escaped to England after the Revolution, joined the Royal Flying Corps, and worked for the Belgian airline and later the Dutch, where he became part of KLM's "iron reserves." When Smirnoff died in mid-1959, all that remained of the Russian soldier was the name; his life's activities had turned him unmistakably into a Dutchman. In 1928 he flew the Fokker tri-motor on the first scheduled service from Amsterdam to Batavia, when his co-pilot was I. A. Aler, today President of KLM, and his engineer was H. Veenendaal, later KLM Technical Director. After World War II Smirnoff helped rebuild KLM. In this connection the author recalls the erroneous report—which had also been accepted by *Interavia* at the time—that Smirnoff had joined Russia's Aeroflot after World War II. The Editors welcome the opportunity of correcting this error. He.

Balloon, Flying-Machine, Helicopter: Further Studies in the History of Terms for Aircraft in English.— By Svante Stubelius. In the Gothenburg Studies in English series (IX). Edited by Frank Behre, Professor of English at the University of Gothenburg. Gothenburg, 1960 (distributed by Almqvist & Wiksell, Stockholm; English; 396 pages; price SKr.35.—).

The name of the editor and of the series indicates that the interest of this study is primarily linguistic; those looking for a kind of pocket technical dictionary with derivations of everyday aeronautical terms may be somewhat disappointed. The selection of expressions is too limited and the vocabulary not sufficiently up-to-date to satisfy such wishes, for although the book includes very new words such as "pilotless aircraft" "guided missile" etc., a number of obsolete terms are followed back to their French, German, Latin or Greek roots. After this necessary caution has been given, however, it should be emphasized that the author's knowledge of aviation is as profound as his knowledge of philology and that this study, like the first part, "Airship, Aeroplane, Aircraft," which appeared in 1958, is an invaluable addition to any aviation library. He.

Die Verkehrsbeziehungen der schweizerischen Flughäfen. — Ey Professor Kurt Leibbrand, 1960 (German; duplicated typescript; obtainable from Lichtpausanstalt L. Speich, Zurich 2, Brandschenkestrasse 47/49, on payment of printing costs of SFr. 6.—).

An inquiry made by voluntary workers among passengers at Swiss airports to obtain certain information on air and tourist traffic: entry zones, transport services to the airport etc. A modest contribution to air transport statistics, since the investigation had to be limited to two days per airport, but nonetheless a useful piece of work. He.

Allein mit Wind and Wolken.— By Philips A. Wills Franckh'sche Verlagsbuchhandlung, Stuttgart, 1960 (German, translated from the English by Georg Brütting, title of original edition "On Being a Bird"; 174 pages; clothbound, price DM 16.80).

Though the German version of these excellently written memoirs by well-known sailplane pilot Philip A. Wills appears some years after the original English edition, it has nevertheless lost nothing of its value. World champion Wills addresses not only gliding enthusiasts, but also has the gift of interesting the layman in this form of sport. Highly recommendable. De.

Air Technical Dictionary: German-English. — Edited by H. L. Darcy. Nine collaborators. Verlag Walter de Gruyter & Co., Berlin, 1960 (XIV+312 pages; cloth-bound; price DM. 38.—).

The fact that German scientists and engineers have brought out a dictionary of aeronautical terms for the English-speaking reader is evidence of how rapidly the importance of the German Federal Republic is growing in aircraft design and industry. In selecting and arranging their material, the compilers have relied largely on American sources, in particular the "United States Air Force Dictionary." The dictionary contains more than 25,000 words. He.

An Introduction to Astrodynamics. — By Robert M. L. Baker Jr. and Maud W. Makemson. — Academic Press, New York and London, 1960 (English; 358 pages; price $7.50).

In the introduction to this book, astrodynamics is defined as "the engineering or practical application of celestial mechanics and other allied fields... to the contemporary problems of space vehicles." The book is thus designed not for the astronomer or astrophysicist, but for the engineer who calculates and determines the trajectories of space vehicles. The first part "Fundamentals and Background" deals with the classical laws of celestial mechanics in five chapters: Introduction; The Minor Planets; the Comets; Geometry and Coordinate Systems; and Astrodynamic Constants. The main part of the book gives more detailed analyses of problems affecting space vehicles: orbit determination and improvement; the N-body problem; special and general perturbations; non-gravitational and relativistic effects; observation theory; application to interplanetary orbits.

No special training in astronomy is required of the reader, though a sound knowledge of higher mathematics is essential for an understanding of the subject matter. The authors know how to present the essentials of each problem, avoiding long digressions without in any way abandoning scientific accuracy. The book will perform good service as an introduction to a complicated branch of science. Readers who wish to penetrate further into the subject will find 175 literary references at the end of the book. There are also a short glossary of technical terms and a subject index. Pr.

Bergman's Linear Integral Operator Method in the Theory of Compressible Fluid Flow. — By M. Z. v. Krzywoblocki (with an Appendix by Ph. Davis and Ph. Rabinowitz). Springer-Verlag, Vienna, 1960 (English; 188 pages; cloth-bound; price $12.40).

One of the consequences of scientific progress is that technical literature is showing an increasing tendency to abandon the book for the periodical, the scientific report or the printed proceedings of conferences. Despite current highly-developed documentation techniques, it is often difficult to obtain a coherent idea of a given branch of science. The author, holder of six University degrees and professor at the University of Illinois, is to be congratulated on his clear, richly referenced symposial presentation of the method of dealing with the theory of compressible fluid flow developed by Bergman and hitherto discussed mainly in mathematical periodicals. The book is the more welcome as the subject dealt with is highly specialized and demands a profound knowledge of higher mathematics and the theory of flows on the part of the reader. Pr.

Magnesium and Its Alloys. — By C. Sheldon Roberts. — John Wiley & Sons, Inc., New York and London, 1960 (English, 230 pages; price $9.00).

This short volume contains the most important information on a metal and its alloys which are becoming increasingly significant in aviation and astronautics owing to their low specific weight. Departing from the physical properties of the element magnesium, the author passes via the theory of magnesium alloys to binary and ternary alloy systems (diagrams) and then discusses in detail the behaviour of magnesium alloys under deformation and changes in temperature. The following chapters deal with casting and wrought alloys, chemical properties (with particular reference to surface protection) and finally extraction and refining. The main stress throughout is on the physical aspects of metallurgy; extraction, working and refining techniques are discussed only marginally. One of the book's main virtues lies in its attractive presentation, to which the many carefully laid out diagrams make a not inconsiderable contribution. There are bibliographies at the end of each chapter, and a subject index. Pr.

Gasturbinen — Arbeitsweise, Gestaltung und Anwendung. — By Prof. K. Leist, Aachen. — No. 22 of the TR-Sonderreihe, Technische Rundschau, Hallwag, Berne, 1960. — Obtainable in Germany from Hallwag GmbH, Spittelerstrasse 8, Stuttgart; in Austria from Hallwag, Kohlmarkt 11, Vienna. — Price Sfr./DM 5.80.

The success of jet engines and propeller turbines in aircraft construction during the last ten years has pushed the piston engine into the background as a combustion engine. The gradual disappearance of the piston engine from aviation should not, however, lead us to the conclusion that the same trend is affecting static installations and the engines of surface vehicles. As the author states in some detail, the characteristics of the gas turbine do not make it the ideal powerplant for every application; nevertheless, it is coming increasingly to the fore in applications outside aviation.

In further chapters the author discusses the method of operation, economic aspects and fuel problems affecting the gas turbine. The great variety of forms which such engines can take can be appreciated from the detailed descriptions of small gas turbines and turbines to power ships, locomotives, static installations, aircraft and nuclear reactors. The text of the publication concluded with a survey of development trends. A comprehensive bibliography will assist the reader in selecting further reading matter. Ba.

Hyperstatic Structures. Volume Two: Worked Examples and Examples for Solution. — By J. A. L. Matheson and A. J. Francis, with chapters by N. W. Murray and R. K. Livesley. — Butterworths Scientific Publications, London, 1960 (English; 282 pages with numerous illustrations; Price 60/-).

Professors are sometimes reproached for the reason that, while they give their students a thorough preparation for examinations, they do not adequately equip them for professional life. The ability to "cram" scientific facts from lectures or books does not imply the ability to use them as tools for practical purposes. The knowledge of how a formula is derived is not sufficient to guarantee its proper application.

Among the branches of science where the transition from theory to practice is attended by considerable difficulties is the theory of structures, where a relatively small number of basic methods of calculation must be used to cope with an infinite variety of practical tasks. Dr. Matheson and Dr. Francis have not lost sight of this fact; although in the first volume of their text-book on statically indeterminate structures they selected only a few examples for discussion, they have made up for this in the second volume, which contains nearly 400 worked examples and examples for solution. The terminology and layout are similar to those of the first volume, to which reference is frequently made. The headings of the nine chapters are as follows: Hyperstatic Structures: Preliminary Considerations; Energy Methods; Deflexion of Structures; General Methods for Linear Elastic Structures; Moving Loads on Structures; Frames with Rigid Joints; Arches; Stability of Struts and Frameworks; Matrix Methods. Each section contains a few examples worked out in detail, which are mainly concerned with civil engineering (bridge building, crane building etc.); many examples are based on building work already done. All the solutions are given at the end of the book. As will be seen from the footnotes, the examples are mostly examination questions set in British and Australian universities in recent years. The logical arrangement, the clear presentation and the careful choice of examples will ensure the book a wide following. Pr.

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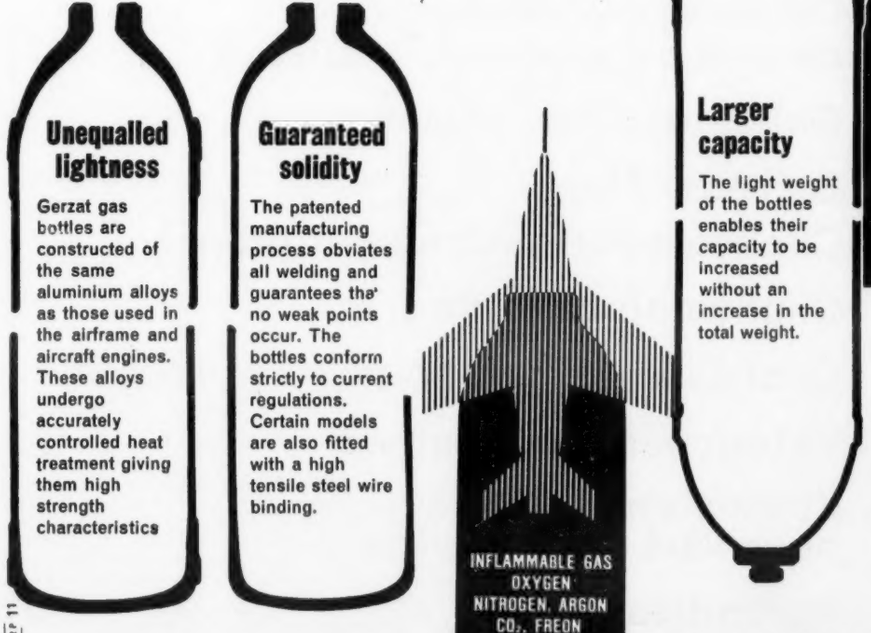

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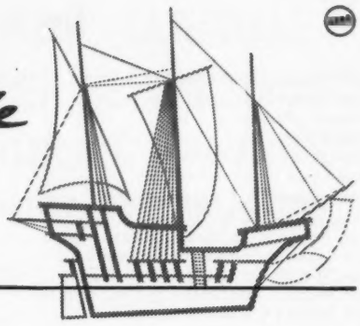

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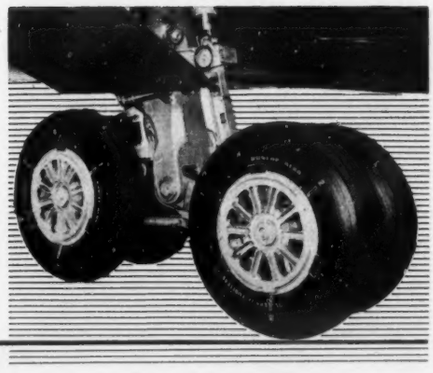

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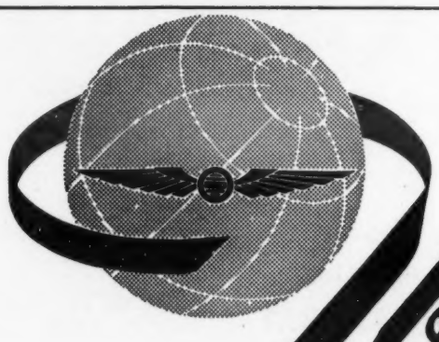
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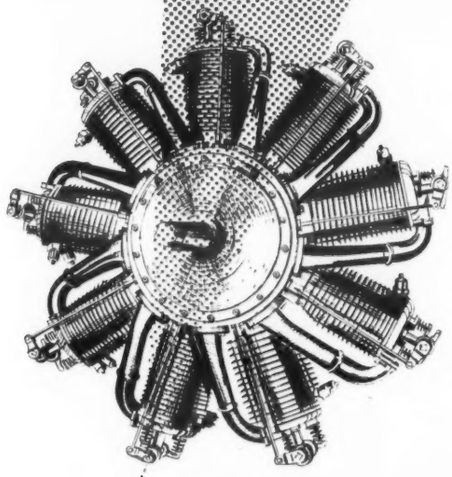

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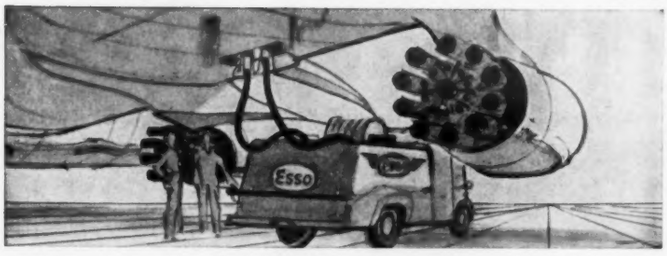

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